



Malawi Soil Health Consortium

Book of Abstracts

Publications on Integrated Soil fertility Management Technologies in Malawi



Ministry of Agriculture, Irrigation and Water Development





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Management Technologies in Malawi

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Development



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A Book of Abstracts of Publications on Integrated Soil Fertility Management in Malawi

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Foreward

This compilation of abstracts and publication titles on Integrated Soil Fertility Management (ISFM) is an endeavor by the Soil Health Consortium of Malawi to facilitate the awareness and access to such information. The main objective of this publication is to provide stakeholders with background research on ISFM components such as varieties, fertilizers, application methods, cropping systems, soil management, agroforestry. Some of the publications are covering case studies of success stories and policy reviews. With such information, stakeholders are encouraged to identify, within their contexts, factors that unlock yield or responses to applied technologies. Further, the book will reduce duplication of research, errors, and encourage scaling out of success stories.

The authors would like to thank the Alliance for Green Revolution in Africa (AGRA) for supporting the activities of the consortium since 2013 including this publication. We also thank the International Plant Nutrition Institute (IPNI) for the technical backstopping and encouragement to produce this book. We also thank all members of the consortium who helped in various ways to access publications. We extend special thanks the Country Director for World Agroforestry Centre (ICRAF) at Chitedze Research Station, The Director for the Department of Land Resources and Conservation, The Director of Agricultural Research Services for their excellent collaboration on the same.

Professor George Y Kanyama Phiri

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Part 1: Soil Fertility Status

1.1 Soil nutrient status of smallholder farms in Malawi

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A soil sampling exercise was conducted throughout 60% of the smallholder farm sector of Malawi, a small country located at the base of the Great Rift Valley. Soil samples (1,130) were geo-referenced and analyzed for pH, texture, soil organic carbon (C), phosphorus (P), zinc (Zn), potassium (K), and calcium (Ca) status. Descriptive statistics of soil characteristics were used to evaluate soil fertility for two agricultural districts in Northern Malawi, two agricultural districts in Central Malawi, and one agricultural district in Southern Malawi. Generally soils were loamy sands and moderately acid, with "low" to "sufficient" nutrient levels. Over three-quarters of soils sampled had organic C levels which were greater than 0.8%. This indicated that organic C status was adequate in the main to maintain soil structure, although much reduced from the non-cultivated state. The organic C data supported observations of widespread nitrogen (N) deficiency in Malawi. High spatial variability of P and Zn values was noted. However, over 60% of soils had a P status above the critical value of 15 mg kg⁻¹ which was sufficient for smallholder maize production levels. This finding supported efforts to alter the current country-wide fertilizer recommendation of 45 kg ha⁻¹ phosphate. New findings reported here were location specific edaphic problems: i) widespread moderate soil acidity in Central Malawi, ii) natural regions in Central and Southern Malawi which were low in P and Zn, and iii) natural regions in Southern Malawi were very low in organic C. Research requirements were identified. Suggested priorities for technology development were those appropriate to smallholder farmers, such as combined use of small amounts of inorganic and organic fertilizers to address very nutrient deficient soils

Citation: Snapp S.S (1998). Soil nutrient status of smallholder farmers of Malawi, *Communication in Soil and Plant Analysis* 29 (17&18): 2571-2588.

1.2 Mehlich 3 extractant for Malawi soils

Wendt J.W.

The Mehlich 3 (M3) universal soil extraction method was compared with the ammonium acetate (AA), Bray 1, and DPTA extraction procedures for the analysis of calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe). Upland Malawi soils from 112 smallholder farmers' fields of the Alfisol, Ultisol, and Oxisol soil orders were analyzed by the four procedures. Calcium, Mg, and K extracted by the M3 and AA procedures were highly correlated ($r^2 = 0.98, 0.98, \text{ and } 0.99$ for the respective elements). The M3 extractant also correlated well with the DPTA procedure for Zn and Cu ($r^2 = 0.88$ for both elements) and the Bray 1 method for P ($r^2 = 0.80$). Amounts of Mn and Fe extracted by M3 and DPTA were poorly correlated ($r^2 = 0.28$ and 0.47 , respectively), with both elements testing high in all soils. The high levels suggest that Mn and Fe deficiencies are likely to be rare, and that analysis for these elements is not generally necessary. Special precautions for Zn and Cu analyses are advised due to the low concentrations of these elements in the M3 extract and various laboratory sources of Zn contamination. The use of soil pH along with M3-extractable Zn is recommended in the identification of potentially Zn deficient soils. The preference for expressing analytical results on a volume rather than weight basis is discussed. Based on a review of literature relating to the M3 extractant, the following critical M3 soil test values are tentatively recommended for maize on upland Malawi soils: Ca, 50 mg/dm³; Mg, 75 mg/dm³ and Mg:Ca ratio >0.067 ; K, 70 mg/dm³; P, 20 mg/dm³; Zn, 1.0 mg/dm³; and Cu, 0.5 mg/dm³. These suggested values should not preclude in country correlation studies. Because the M3 procedure is well correlated with the AA, DPTA, and Bray 1 methods, and because it is a rapid procedure, the M3 method can be highly recommended as a replacement for the three current procedures for Malawi upland soils. Caution is advised in extending the results to Malawi lowland soils, which are characterized by higher pH values.

Citation: Wendt JW. 1995 Mehlich-3 soil extractant for Malawi soils. *Communication in Soil Science and Plant Analysis* 26 (5&6): 687-702.

1.3 Mehlich 3 or Modified Olsen for Soil Testing in Malawi.

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Soil nutrient extraction methods, which are currently being used in Malawi, are time consuming and require too many resources. The use of a universal soil extractant would greatly reduce resource requirements. The objectives of the study were to (i) compare the universal soil extractants, Mehlich 3 (M3) and Modified Olsen (MO) with ammonium acetate (AA), Bray P1 (BPI), and diethylene triamine penta acetic acid (DTPA) in the amount of nutrients extracted, (ii) determine the relationship among the extractants for the nutrients they extract, and (iii) determine the critical soil test levels of phosphorus (P), potassium (K), and zinc (Zn) for a maize crop. Missing nutrient trials involving P, K, and Zn were conducted on thirty sites across Malawi using maize (*Zea mays* L.). Phosphorus application rates ranged from 40 to 207 kg P₂O₅ ha⁻¹. Potassium and Zn were applied at 75 kg K₂O and 10 kg Zn ha⁻¹, respectively. Procedures of Cate and Nelson were used to identify soil nutrient critical levels. Results showed that the correlations between M3 and BPI, and MO and BPI were highly significant ($r=0.93, 0.94$, respectively). Mehlich 3 extractable K and AA extractable K ($r=0.90$), MO and AA extractable K ($r=0.94$) were highly significant ($P<0.01$) and the correlations between M3 and AA and MO and AA extractable calcium (Ca) ($r=0.92, 0.90$, and 0.94 , respectively) were also highly significant ($P<0.01$). The correlations between M3, MO, and AA extractable magnesium (Mg) ($r=0.99$) were highly significant ($P<0.01$). Zinc, copper (Cu), and manganese (Mn) extracted with M3 and DTPA were significantly correlated ($r=0.89, 0.87$, and 0.95 , respectively). Correlations between MO and DTPA extractable Zn, Cu, and Mn were also highly correlated ($r=0.89, 0.85$, and 0.95 , respectively). Maize grain yields ranged from 730 to 9,400 kg ha⁻¹. Mehlich 3-P and MO-P critical levels were 31.5 and 28.0 $\mu\text{g g}^{-1}$, respectively. Mehlich 3 and MO gave a similar critical level of 0.2 cmol kg^{-1} for K while Zn critical levels were 2.5, and 0.8 $\mu\text{g g}^{-1}$ for M3 and MO, respectively. Mehlich 3 and MO were equally effective in separating responsive to none responsive soils for maize in Malawi.

Citation: Chilimba ADC, Mughogho SK and Wendt J. 1999. Mehlich 3 or Modified Olsen for Soil Testing in Malawi. *Commun. Soil Sci. Plant Anal.*, 30 (7&8), 1231-1250.



Part 2: The Use of Organic Fertilizers

2.1 Improving organic matter management in smallholder farming systems of Malawi through compost of crop residues and animal manure: a survey for management of manure and crop residues in Malawi

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A survey was conducted in Blantyre, Lilongwe and Mzuzu Agricultural Development Divisions using a structured questionnaire in April, 1999. The aim of the survey was to collect information of the utilization of animal manure and crop residues by smallholder farmers. Although the national cattle herd in Malawi is low, some areas have high concentration of animals such as south Mzimba in Mzuzu ADD. In the survey it was evident that the value and the use of manure varies between areas, in areas where animal manure is in abundance, it has less value and it underutilized. In all the survey areas a little crop residue was incorporated, as most crop residues were fed to cattle in the dry season under free range grazing system. In Mzimba rotation of Khola (livestock enclosure) was common. Farmers indicated that the soil fertility benefits and minimizing dung accumulation in the khola during the rainy season were the main seasons for rotating the khola. The average khola size ranged from 120-200 m²

Citation: Sakala WD, Kamanga B, Kumwenda JDT, Benson T and Ligowe I (2001). Improving organic matter management in smallholder farming systems of Malawi through compost of crop residues and animal manure: a survey for management of manure and crop residues in Malawi, Maize Commodity Team Annual report for the 1998/99 cropping season, Department of Agricultural Research Services, Lilongwe, Malawi.

2.2 A proposal to release DI grow liquid organic fertilizer for maize production in Malawi

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A factorial study on evaluation of DI grow liquid organic fertilizer was conducted at Chitedze and Bvumbwe research stations in the 2011/12 growing season and under farmers field in Malosa irrigation scheme. The objective of the study was to evaluate application of D.I Grow liquid foliar fertilizer in improving maize production. Data was analyzed using a two-way analysis of variance (ANOVA) to compute the significance of the treatments. Results have shown that application of inorganic fertilizer application significantly ($P < 0.001$) increased maize grain yield both at all sites. DI grow organic fertilizer significantly increased ($P < 0.01$) maize grain yield only at Bvumbwe site. There was also little evidence on the interaction between inorganic fertilizer and DI Grow fertilizer in increasing maize grain yield at all sites. Despite this, the highest maize grain yields at all sites were obtained where there was application of a combination of inorganic fertilizer and DI Grow. At Bvumbwe and Malosa sites full rate inorganic fertilizer plus full rate D.I Grow gave the highest grain yields (7.7t/ha and 6.1t/ha respectively). At Chitedze the following applications gave the highest yields were obtained from full rate inorganic plus one and a quarter rate DI Grow application which gave 7.4 t/ha of maize grain. An economic analysis showed that the highest net benefits at Bvumbwe were obtained where maize received (i) quarter rate inorganic fertilizer plus quarter rate D I grow (ii) one and a half rate DI grow plus full rate inorganic fertilizer and (iii) full rate of D.I grow plus full rate inorganic fertilizer. At Chitedze highest net benefits were obtained where there was application of (i) half rate inorganic fertilizer plus full rate D.I Grow fertilizer, (ii) full rate inorganic fertilizer plus quarter rate of D.I Grow, and (iii) full rate inorganic fertilizer plus one and a quarter rate of DI grow, in their descending order. It is thus deduced, that the aforementioned fertilizer applications provide the economically viable options for maize production in Malawi. As was hypothesised, supplementation of inorganic fertilizer with DI Grow can improve maize production. This could therefore reduce overdependence on inorganic fertilizers. Results have also shown that applications of both inorganic fertilizer and DI Grow significantly ($P < 0.001$), ($P < 0.01$) increased maize biomass yield respectively. There was also a significant synergy ($P < 0.05$) between the two in increasing maize biomass.

Citation: Munthali C (2012). A proposal to release DI grow liquid organic fertilizer for maize production in Malawi, Technical report, Department of Agricultural Research Services, Lilongwe 3, Malawi

2.3 The role of mycorrhizal fungi in soil restoration, nitrogen fixation, nutrient translocation, carbon sequestration and water dynamics

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Much of the research has been done on the arbuscular mycorrhizal (AM) fungi in soil restoration, nitrogen fixation, nutrient translocation, carbon sequestration and water dynamics in universities and research centres on the world. Mycorrhizal fungi or fungus roots evolved with terrestrial plants in a symbiotic relationship, extending far into the soil and providing much needed nutrients such phosphorus, nitrogen, zinc, iron, calcium, magnesium, manganese, and sulfur. Shoots from the mycorrhizal plants averaged 30 percent higher nitrogen content 300 percent higher phosphorus content than shoots from non-mycorrhizal plants. The mycelial network can extend across many hectares, well beyond the zones occupied by the roots and root hairs. Plants seeded into the networking have the advantage of a pre-existing root network that they can tap into. The absorptive area of mycorrhizal fungi is 100 times more effective than that on roots. Ground breaking research at Cornell University in the US has recently proven that arbuscular mycorrhizal (AM) fungi networks can connect roots of plant and translocate nutrients between them. This is particularly interesting in relation to maize, where the mycorrhizal hyphae enable direct translocation of rhizobium-fixed nitrogen flow, demonstration that AM hyphae translocate legume-fixed nitrogen to maize during the same when plants shared the same rhizosphere. This is in opposition to the common assumption that rhizobium-fixed nitrogen is only available after root senescence and demineralization. AM fungi have also a role in nitrogen fixation. Rhizobium nodules are not able to fix nitrogen without sufficient phosphate. The enzymes on the tips of the hyphae are able to dissolve rock and translocate phosphorus to the nitrogen fixing nodules. Mycorrhizal fungi have an active role in soil formation and carbon sequestration. Glomalin, the sticky coating around the mycorrhizal hyphae hold together aggregates to give soil structure, it is glomalin that gives soil its tilth. Glomalin provides food for soil organisms. The US Department of Agriculture Researchers have determined AM fungi is responsible for a third of the world's stored soil carbon. AM fungi play an extremely important role in water dynamics, the expanded and enormous absorptive surface area connected to the roots ensures that nearly all moisture in a plant's surrounding soil is accessed. When a root cell becomes colonized by a mycorrhizal fungus, a special shared organ called a vesicle grows inside the root cell. The vesicle is a storage container for water and dissolved nutrients that can be utilized in times of deficiencies, such as drought periods.

Citation: Swithenbank G (2014). The role of mycorrhizal fungi in soil restoration, nitrogen fixation, nutrient translocation, carbon sequestration and water dynamics, In: Kabambe V, Tembo Y and Ngwira A, editors. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 12-26

2.4 Whither biofertilizer technologies in Malawi?

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The decline in soil fertility and productivity continues to be a big challenge for Malawi and other countries in sub-Saharan Africa. Low productivity of soil is aggravated by poor soil management practices including low application of inorganic fertilizers and poor management of organic sources by the predominately smallholder farming systems, and in the recent years these are also exacerbated by population pressure and climate change effects. These challenges call for holistic approaches to soil fertility management options that consider all possible options including cheap but also environmental friendly interventions. Recent advancements have seen more of biofertilizer technologies in some parts of the world than in others. Research advances have led to the use of various biofertilizer inoculants including nitrogen fixers, phosphate and potassium solubilizers and composting process enhancing inoculants. This paper is aimed at looking the state of biofertilizer technologies in Malawi. An effort is made in highlighting some commonly used biofertilizer technologies in Malawi and other countries, and review the opportunities and challenges faced by Malawi in the work of advancing biofertilizer technologies

Citation: Njira K. O. W, (2014). Whither biofertilizer technologies in Malawi? In: Kabambe V, Tembo Y and Ngwira A eds. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi, SoHCoM Publication 09, pp. 27-40

2.5 Quality assessment of compost manure produced by smallholder farmers in Malawi

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Smallholder farmers are making compost manure using various sources of plant materials but the quality of the compost manure has not been assessed although the beneficial effects of applying manure are well known. Therefore the quality of compost manure made across the country with their effect on maize yield was assessed. Analytical results showed that N, P, K, Ca, Mg, Zn and Cu ranged 0.21 to 2.2%, 0.05 to 0.73%, 0.12-2.62%, 0.19 to 10.1%, 0.15 to 2.43%, 37 to 208 mg kg⁻¹ and 12 to 87 mg kg⁻¹ respectively. The application of 5000kg ha⁻¹, the compost would supply N, P and K ranging from 10 to 74, 5 to 10 and 17 to 37 kg ha⁻¹ across the country respectively. To balance the N to attain the recommended rate, application in the range of 82 to 18 kg ha⁻¹ need to be applied. However, compost manure supplied adequate amount of K for maize production. In addition the compost manure supplied S, Ca, Mg, Zn and Cu in the range 4-13, 50-90, 29-75, 0.4-0.6 and 0.2 -0.6 kg ha⁻¹ respectively. Increased use of compost manure as part of integrated soil fertility management in Malawi would reverse soil fertility decline and land degradation and improve food security.

Citation: Chillimba A.D.C, Shano B, Chigowo M.T and Komwa M.K, (2014). Quality assessment of compost manure produced by smallholder farmers in Malawi, In: Kabambe V, Tembo Y and Ngwira A, eds. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 142

2.6 Evaluation of compost manure making and utilization by smallholder farmers: a case study of Blantyre ADD

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In Malawi, the Ministry of Agriculture and Food Security (MoAFS) has been promoting the use of compost manure and other technologies that build the soil organic matter in order to improve the soil fertility and crop productivity on resource poor farmers' fields. Farmers were making different types of compost manure using various sources of plant materials. A case study was conducted based on a five-year (2008/09) to 2012/13) secondary data from the annual reports generated by the department of land resources to evaluate the trend of compost manure making and utilization by farmers in Blantyre Agricultural Development Division. The study findings have however revealed, despite all annual national campaigns and other strategies put in place, farmer's uptake/adoption of the technology on compost manure making and utilization to improve soil fertility is still left to be desired. The adoption rate is very low; two heaps are being made per household each year. This coupled with low nitrogen content of composting materials, soil improvement results do not manifest immediately in crop yields in the short term- especially when spread injudiciously within their fields. From the findings of the case study, it is therefore recommended that quality of compost manures be improved if farmers are to take up the technology and there is also a need to improve extension campaign strategies.

Citation: Chigowo MT (2014). Evaluation of compost manure making and utilization by smallholder farmers: a case study of Blantyre ADD, In: Kabambe V, Tembo Y and Ngwira A, editor. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 101-108

2.7 Effects of composting materials on nutrient content and maturity time

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Application of organic manure is a valuable restoration strategy that can alleviate the physical conditions and improve the nutrient status of degraded soil. To get maximum benefit, proper selection of composting material, management and nitrogen turnover of these materials need to be examined. The study to this effect was done and the aim of the study was to investigate the effect of different composting material (leguminous and non-leguminous) on nutrient content and time of maturity. The study involved the mounting of demonstration trials at different areas. They were located at Luangwa Research Station and four other sub-stations of Bolero, Nchenchena, Mkondezi and Mbawa to expose the trials to different agronomic conditions. The demonstration trials were also exposed to different environments namely plastic, open and shade. The preliminary results are showing that there are no significant differences on the nutrient content of manure made from different material combination but leguminous materials have high potential of providing nitrogen to plants. However, combination of different materials speeds up process.

Citation: Kaunda G (2014). Effects of composting materials on nutrient content and maturity time, In In: Kabambe V, Tembo Y and Ngwira A, eds. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 144

2.8 The development and contribution of surface charge by crop residues in two Malawian acid soils

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The effects of maize and soya bean residues on the pH and charge of loamy sand (Kawalazi) and a sandy clay loam (Naming'omba) from Malawi were measured to determine both the indirect effect of the residues on soil charge through the changes in pH, and the direct contribution of charge carried on the residue surfaces. The soils had pH values (10 mm CaCl₂) of 4.3 and 5.0 and organic matter contents were 1.4% and 2.7%, respectively. The clay fractions were dominated by kaolinite and goethite, and mica was present in both samples. The soils were incubated for 28 days with maize (*Zea mays*) and soya bean (*Glycine max*) residues. The maximum addition of residue (12.0%) in the Kawalazi and Naming'omba soils increased the pH from 4.3 and 5.0 to 4.8 and 5.3 (maize) and to 9.0 and 8.8 (soya bean), respectively. Negative charge increased from 2.1 and 4.7 cmolc kg⁻¹ to 3.8 and 7.5 (maize) and to 5.3 and 9.3 cmolc kg⁻¹ (soya bean). Positive charge increased from 0.72 and 0.62 to 0.87 and 0.85 cmolc kg⁻¹ (maize) and to 0.75 and 0.68 (soya bean). The charge contribution by the residues was calculated by difference between the charge on a sample incubated with residue and the charge on a soil without residue limed to the same pH value. Up to 100 cmolc negative charge and 10 cmolc of positive charge per kg of residue were directly contributed to the soil-residue mixture, the amounts depending on the type of residue, the extent to which the residue was decomposed in the soil and the pH of the mixture. The Anderson and Sposito method was used to partition the permanent negative charge (holding Cs⁺) from variable negative charge (holding Li⁺). In the pH range 3.7–6.5 the maize residue contributed between 3 and 26 Cmolc of variable charge per kg of residue in the Kawalazi soil and between 6 and 25 Cmolc per kg of residue in the Naming'omba soil. For soya bean the values were between 1 and 28 and between 4 and 68 cmolc per kg of residue, respectively. At a given pH value, the charge tended to increase with time of incubation and for a given addition of charge and the charge on the soil measured by Cs adsorption was independent of pH change caused by the residue showing that the method is valid for soil-residue mixtures. With time there was a decrease in the amount of permanent charge probably due to masking as humic material become adsorbed on mineral surfaces.

Citation: Nkhalamba J.M, Rowell D.L and Pilbeama C.J, (2003). The development and contribution of surface charge by crop residues in two Malawian acid soils, *Geoderma* 115, pp. 281– 302

2.9 Beneficial effects of microbes in nutrient recycling in cropping systems of Malawi

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The major constraint to agricultural production in Malawi is soil fertility decline. The beneficial effects of microbes in the soil, in sustaining soil productivity are promoted in the country through the introduction of organic matter technologies. However, the effect of using maize stover on long term soil fertility improvement has not been assessed in the country. Maize stover is the most abundant crop residue in different cropping systems and could sustain soil productivity if properly utilised. Research was initiated to evaluate the long-term effects of incorporating or removing maize stovers on soil fertility, microbial activities and crop yields at two sites. Mulching significantly increased grain yield in the third season at both sites although yield reduction was experienced in the first and second season due to mulching. Mulching and nitrogen application enhanced microbial activities, which is essential in nutrient recycling. Mulching significantly reduced soil pH, available phosphorus and exchangeable potassium in the first and second seasons. However, mulching increased soil pH, soil organic matter, exchangeable potassium, calcium and available phosphorus in the third and fourth seasons and maize yields significantly increased with mulching in third and fourth seasons. The results show that boxed ridging and maize stover mulching is sustainable because soil microbial activities and soil productivity improved in long term. Soil nutrient immobilization was not observed in the third and fourth seasons indicating that microbes play a very important role in nutrient recycling in farmers cropping systems.

Citation: Chilimba ADC (2002). Beneficial effects of microbes in nutrient recycling in cropping systems of Malawi, *Trop. Microbiol.* 1.: 47–53.

2.10 Evaluating the effects of ocean harvest, an organic liquid nutrient catalyst on maize production under rain fed conditions in Malawi

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In 2010-11 cropping season, an exploratory experiment was set up at Chitedze and Chitala Research Stations to evaluate the efficacy of using ocean harvest as a nutrient catalyst for maize production in Malawi. In the second phase of experimentation, 2011-12 cropping season, trials sites were extended to farmers fields across agroecologies in the country. Targeted trial sites included: Karonga, Kasungu, Salima, Balaka, Lilongwe and Ntchisi districts. Nine different experimental treatments were consistently evaluated in a Randomized Complete Block Design (RCBD) replicated three times. Treatments were evaluated either as sole applications of inorganic and Ocean Harvest nutrient sources or in combinations of the two. Results indicate significant differences ($p=0.05$) on maize stem diameter, plant height and grain maize due to treatments effects. Best results on variables tested were obtained where 100% of phosphorus and nitrogen were supplied from inorganic fertilizer sources. Lowest responses were obtained from the control treatment that received no nutrient of any kind. No significant differences ($p=0.05$) existed between combined applications of the two nutrient sources treatment and the 100% inorganic applied treatment. In combined application treatments, sequence of application gave comparable performance to the 100% organic fertilizer application. At some sites, no significant differences existed between the control treatments and sole applications of Ocean Harvest irrespective its concentrations and methods of application on crop performance. Sites x treatments integrations were significantly observed ($p=0.05$) on grain yield.

Citation: Kamalongo D, Makumba W.I, Ngwira A, Ligowe I, Kazombo S and Sichinga N, (2013). Evaluating the effects of ocean harvest an organic liquid nutrient catalyst on maize production under rain fed conditions in Malawi, Maize Commodity Team annual research project report for 2011/12 cropping season, Department of Agricultural Research Services, Lilongwe, Malawi

2.11 Effects of nitrogen sources and rates on maize yield in Malawi

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The objective of this study was to determine the effect of different nitrogen (N) sources and rates on hybrid maize yield at 22 sites throughout Malawi. Four N sources, common (prilled) urea, granular urea, sulphate of ammonia (S/A), and calcium ammonium nitrate (CAN), each at four levels of N; 0, 50, 100 and 150 kgNha⁻¹ were tested on hybrid maize. At 20 sites all four rates gave similar maize yields, while at 2 sites urea N sources reduced maize yield due to maize seedling injury. Maize response to N rates varied from location to location. At 17 sites maize yield increased significantly ($P\leq 0.001$) with the first 50 N increments, while at 5 sites maize increased significantly ($P\leq 0.001$) with an application of both 50 and 100 kg N ha⁻¹. A further increment to 150 kg N ha⁻¹ did not significantly increased yield at any sites studied. These data show that if urea N sources are properly place all nitrogen sources are equally effective. However, there is need to establish site specific recommendations for N fertilizers

Citation: Kumwenda J.D.T, Kabambe V.H, Sakala W.D and Ngwira L.D.M, (undated), Technical report, Chitedze Agricultural Research Station, P.O Box 158, Lilongwe, Malawi

2.12 Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa

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One of the biggest challenges in the tropics is to develop organic matter technologies which are adopted by farmers. Technologies must be effective within farmer resources constraints, increase food production, reduce risk and enhance soil fertility. Results from on-farm participatory research were used to quantify the effects of agronomic practices on soil resources. Agricultural productivity is primarily nitrogen (N) limited throughout Malawi and sub-humid Zimbabwe. Tightening economic constraints faced by farmers in the region have reduced inorganic fertilizer inputs and increased resilience of biologically fixed N and N cycling. Three components of organic matter quality were evaluated: (1) the effect of residue quality; (2) the role of deep rooting systems; and (3) tradeoffs between legumes grown for grain versus soil regeneration. Perennial systems investigated include improved fallows, intercropping and biomass transfer. Annual systems include intercrops and rotations of cereals with legumes. The most promising non-food legumes were Tephrosia and Sesbania. Interestingly, high quality residues of perennial legumes were most effective at supplying N in the short to medium term, whereas low quality

residues immobilized N. low quality residues were problematic for smallholder farmers who need immediately available N. challenges to adoption of perennial systems technologies include establishment costs, resource competition and delayed benefits. Farmer adoption of legume production is promoted by the simultaneous production of food; however, especially those which have a high N harvest offer a useful compromise of meeting farmer food security concerns and improving soil fertility. Promising genotypes include *Arachis*, *Cajanus*, *Dolichos* and *Mucuna* spp. On-farm N budgets indicate that legume with high quality residues and deep root systems are effective ways at improving nutrient cycling. Areas of future research priority for smallholder farms in southern Africa were identified, including technologies which combine inorganic and organic fertilizer and improve legume and establishment on degraded soils.

Citation: Snapp S.S, Mafongoya P.L and Waddington S, (1998). Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa, *Agriculture Ecosystems and Environment* 71, pp. 185-200

2.13 The response of maize and beans to *Leucaena* prunings

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Between 1972/73 and 1982/83 growing seasons, the price of the fertilizers commonly used by the smallholder farmers in Malawi rose by 293%. With this increase, the possibility of a smallholder farmer growing a fast growing nitrogen fixing tree such as *leucaena* and using fine stems and leaf prunings as green manure to meet some of his fertilizer requirement and hence reduce production cost was investigated. Three field experiments were conducted. Results showed that the 10 tons/ha of *leucaena* prunings yielded 3159 kg/ha of maize. In another companion experiment in which different rates of *leucaena* prunings were used, the results showed that the additional of prunings increased maize seed yield. The yield from 5 tons/ha of *leucaena* and 52kg /ha of 20-8. 7-0 and 52 kg/ha N. *Leucaena* prunings also increased bean seed yield but the results less dramatic than those maize. It is proposed farmers wishing to use *leucaena* leaves as fertilizer could grow the plant along bunds, in strips across their farms, along farm boundaries or as hedge plants. At a density of 10, 000 plants/ ha of *leucaena*, a farmer should be able to realize the equivalence of three bags of calcium ammonium nitrate or about four bags of sulphate of ammonia from fresh *leucaena* prunings from maize and/or dark fired tobacco production.

Citation: O. T Edge, (1983). The response of maize and beans to *Leucaena* prunings, a paper presented at Agroforestry workshop, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi, 28 June- 1 July, 1983.

2.14 Biomass production by legume green manures on exhausted soil in Malawi: a soil fertility network trial for 1997/1998 cropping season

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A SoilFertNet trial was initiated in the 1996/97 growing season to determine if *Mucuna pruriens*, *Crotalaria juncea* or *Tephrosia vogelii* could produce significant quantities of biomass at on-farm sites where maize yields had been greatly depressed due to declining soil fertility. At the five SoilFertNet sites in Malawi, *Mucuna* yielded the most biomass, averaging 7370 kg/ha. These values are higher than Zimbabwe, indicating a higher level of soil fertility even on relatively exhausted sites in Malawi. In 1997/98 season maize will be planted on all plots to determine the residual fertility benefits of the green manure rotation.

Citation: Kumwenda J.D.T and Gilbert R, (1997). Biomass production by legume green manures on exhausted soil in Malawi: a soil fertility network trial for 1997/1998 cropping season Technical report, Chitedze Agricultural Research Station, Lilongwe, Malawi

2.15 Partnership with Malawian farmers to develop organic matter technologies

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One of the biggest challenges in the tropics is to develop organic matter technologies (OMT) which increase production, reduce risk and are taken by the farmers. An interdisciplinary team of researchers, extension staff and farmers addressed this challenge in the southern Malawi. Two watersheds were identified as the primary unit of research, extension and development to test OMTs. This landscape-based approach provided the platform for the interdisciplinary research and, farmer participatory and the community based assessment of OMTs. The on-going processes involves testing a menu of farmers' OMTs recommendations and closely linked process research

conducted in the field. The OMTs with the maize dominated cropping systems of the watersheds was relay intercropping of agroforestry species (*Sesbania sesban* and *Tephrosia vogelii*). Evaluation of OMT performance involved farmer assessment and biological evaluation. Farmer participatory methods included village group and farmer and individual semi structured questionnaires, linear transect walks, and farmers- managed, researcher-designed trials. Biology included monitoring cropping system production, linked with soil nitrogen dynamics and watershed nitrogen budgets to assess sustainability of OMTs, nutrient budgets indicated that system productivity can be enhanced almost two fold by addition of 30 N kg/ha N as an organic or inorganic source and nutrient losses will be lowest with combined OMT plus inorganic fertilizer technology. The poorest farmers with access to small, infertile fields tended to have sandy soil with low nitrate levels and limited growth of *Sesban*. This reduced the benefits of OMT systems. These farmers may be candidates for more intensive use of grain legume intercrops and rotation, as benefits from the grain are needed by these food insecure households, and will complement soil fertility amelioration.

Citation: Kanyama-Phiri G.Y, Snapp S.S and Minae S, (1998). Partnership with Malawian farmers to develop organic matter technologies, *Outlook of Agriculture* Vol. 27 (3), pp, 167-175

2.16 Investigating the effectiveness of integrating vermicomposting and earth worm urine in soil and fertility technologies for increased maize yield

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Soil infertility which leads to increase in production cost due to cost of inorganic fertilizer can be manipulated by application of manure. Usage of inorganic fertilizer without organic application leads to low soil microorganisms which fix nitrogen, solubilise and mobilise phosphates, increase disease resistance, provision of Plant growth promoting rhizobacterial (PGPR). Several methods of composting have been advocated and are being implemented and practiced in Malawi but negligible farmers are practicing vermicomposting. Vermicomposted manure has a positive effect on bacteria, actinomycetes and fungi and makes them more active than other methods of composting. This study investigates the effectiveness of integrating vermicomposting in soil and fertility technologies for increased maize yield

Citation: Mwafulirwa S, Botoman L, Liwimbi L, Munthali C, Malunga C, Manyenga, Chisale M, Chisambi and J Mtefa, (2015). Investigating the effectiveness of integrating vermicomposting and earth worm urine in soil and fertility technologies for increased maize yield, *Soils and agricultural engineering commodity group project reports* (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

2.17 ADDFOOD: A project promoting land husbandry and agroforestry in Malawi, 1990-1994

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The ADDFOOD project, funded by the European Community (EC) and executed by the Ministry of Agriculture and Irrigation, was initiated in 1990 to address the problems faced by the majority of farmers in Malawi who, due to a rapidly rising rural population dependent on agriculture, and consequently declining size of individual holdings, can no longer afford conventional inputs or follow traditional practices to maintain soil fertility and crop yields. Further, the effects of escalating population pressures are the widespread cultivation of the steep and marginal unsuitable for annual cropping giving rise to massive soil erosion, and progressive deforestation for land clearance and the satisfaction of increasing of fuel and building materials. The project is working in some ninety villages of the southern half of the country, where these problems are the most acute, dealing with watersheds and communities rather than individual holding and farmers. Soil conservation measures are followed and reinforced by the introduction of alley cropping, based on appropriate fast growing leguminous tree species, and the planting of *Faidherbia albida*. The ADDFOOD project has followed current research recommendations, but inevitably these have had to be adapted in the light of experience gained under field conditions, and in consideration of what must remain in practicable on a more extensive scale if the project is to make any significant contribution to agriculture production, the creation of stable and sustainable farming system, and protection of the environment.

Citation: Weightman B.L (1994). ADDFOOD: A project promoting land husbandry and agroforestry in Malawi, 1990-1994 Technical Report, Ministry of Agriculture and Irrigation, Lilongwe 3, Malawi

Part 3: The Use of Inorganic Fertilizers

3.1 A green revolution frustrated: Lessons from the Malawi experience

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High population density, small farm size and a monomodal rainfall pattern are the major determinants of smallholder farming systems in Malawi. With over 70% of farming having the total land holdings of less than 1 ha, the farming system is dominated with continuous cropping with maize without fallow and very little rotation. Consequently the nutrient capital of the soils is being depleted and yields are declining. For many years, the government's response to this situation has to intensify the technology based on the use of hybrid seeds and inorganic fertilizers. Originally the entire effort of extension staff was devoted to this strategy, supported by subsidies on credit, input and output prices. As a result, the use of fertilizer and hybrid seed expanded rapidly and in 1992/93 season, this technology had been adopted in almost half of the total maize area. Yields of fertilizer hybrid maize are presently about three times those obtained from the traditional practices, and a number of international observers classified Malawi as an example of African "Green Revolution". Predictions were that by the end of the decade up to 70% of the maize areas would be fertilized and planted with hybrid seeds. Such predictions took inadequate account to the tax-payer of maintaining these distortions once the technology is adopted on a large scale. Subsidies have had to be dropped, both inputs and outputs markets have been liberalized and the currency has been floated. The result has been that the smallholder sector in 1995/96 was able to purchase hybrid seed sufficient to plant only 7% of the maize area, whilst the capita sales of fertilizer for use on maize was lower than they were fifteen years ago. The rapid increase in the price of fertilizer has been unmatched by a rise in grain prices because these are controlled by a purchasing power of the poor population. Increasing fertilizer use has been the engine for growth of agricultural production in much of the world during the past thirty years. The World Bank, among others, has stressed the need for a rapid increase in fertilizer use in Africa if its expanding population is to be fed. It has been stressed that the removal of subsidies, the liberalization of markets and sound currency exchange policies are the vital pre-requisite for achieving this goal. The Malawian experience provides ominous indications that such policies may not achieve their desired results, and has transformed so much of the world's agriculture. This paper provides a detailed analysis of the figure and factors involved in this frustrated Green Revolution and points to their relevance to their countries in the region.

Citation: Carr SJ. 1997). A green revolution frustrated: Lessons from the Malawi experience, African Crop Science Journal 5(1), pp. 93-98

3.2 "Maize is life": Malawi's delayed green revolution

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The pattern of maize seed production in Malawi demonstrates the importance of farmers' capacity to articulate their interests through collective actions and instructions. Despite the vital significance of maize as a wage good in Malawi, limited effective demand for maize seed research prolonged the period of technical stagnation. Analysis of the institutional factors shaping for maize seed research complements previous work of Malawi's political economy, the supply of seed technology and adoption, with implications for current political changes in that nation, the importance of farmers' organizations, and state commitment to agricultural research in the sub-Saharan Africa.

Citation: Smale M, (1995). Maize is life": Malawi's delayed green revolution. World Development, 23 (5): 819-81

3.3 Soil sulphur status and maize response to sulphur application in Malawi

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Sulphur deficiency is increasing in the country and the current sulphur application rate seems not to be adequate. Sulphur in the current fertilizer recommendation supplies 6 and 8 kg S ha⁻¹. Due to lack of information on sulphur status in Malawi soils and appropriate rate of application, sulphur studies were conducted to determine soil sulphur status in Malawi, assess the effectiveness of gypsum as a source of sulphur and determine the optimum rate of sulphur application for maize production. Soil samples were collected in all Extension Planning Areas on Lilongwe Agricultural Development Division and were analysed for sulphur status. Sulphur response studies were conducted in the greenhouse and in the farmers' fields and research stations. Sulphate of Ammonia and gypsum were sources of sulphur and were applied at 0, 10, 20, 30, 40 and 60 kg ha⁻¹.

Sulphur status in Lilongwe ADD showed that 69% of the sampled sites were deficient in sulphur. Soil sulphur critical value determined by the Malawi soils was at 15 mg kg⁻¹ for maize. Maize significantly responded to sulphur application in grain yield and optimum rate of sulphur application identified was 20 kg S ha⁻¹. Gypsum as a source of sulphur was equally effective in increasing maize yield.

Citation: Chilimba A.D.C and Chirwa I.M.D, (2014). Soil sulphur status and maize response to sulphur application in Malawi, In: Kabambe V, Tembo Y and Ngwira A, eds. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 1-11

3.4 Farmer evaluation of phosphorus fertilizer application to annual legumes in Chisepo, Central Malawi

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Building from the perception that farmers have an intimate knowledge of their local environment, production problems, crop priorities and criteria for evaluation, an on-farm experiment was conducted with farmers in 2003/4 in Chisepo, central Malawi, to evaluate the response of six annual legumes to phosphorus (P) (20 kg P ha⁻¹ or no P fertilizer) application. The legumes were velvet bean, pigeonpea, soyabean, groundnut, bunch-type cowpea and Bambara groundnut. Twelve farmers hosted the experiments and each farmer formed a group of at least 4 other farmers to evaluate the legumes. Farmer participatory monitoring and evaluation of the legume and P combinations was conducted during the experiment to determine farmer preferences and acceptance of the technology. Measured grain yields, returns to labour and total costs of the P-fertilized legumes were compared with those for the unfertilized legumes. The application of P fertilizer significantly ($P = 0.05$) increased legume grain yields, particularly with velvet bean, and soyabean. However, use of P was not financially attractive and farmers were not interested to use P at the time. Farmers were more interested to maximize legume food production from their labour investment. Soyabean, groundnut and pigeonpea, grain legumes with high value as food, were considered to be priority crops by farmers over velvet bean, cowpea and Bambara groundnut.

Citation: Kamanga B.C.G, Whitbread A, Wall P, Waddington S.R, Almekinders C and Giller K.E, (2010). Farmer evaluation of phosphorus fertilizer application to annual legumes in Chisepo, Central Malawi, African Journal of Agricultural Research Vol. 5(8), pp. 668-680

3.5 Improving Nitrogen Efficiency: Lessons from Malawi and Michigan

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Two case studies are presented here of nitrogen (N) dynamics in potato/maize systems. Contrasting systems were investigated from (1) the highland tropics of Dedza, Malawi in southern Africa and (2) the northern temperate Great Lakes region of Michigan. Formal surveys were conducted to document grower perceptions and N management strategies. Survey data were linked with N budgets conducted by reviewing on-farm data from representative farms in the targeted agroecosystems and simulation modeling to estimate N losses. Potential N-loss junctures were identified. Interventions that farmers might accept are discussed. The Malawi system uses targeted application of very small amounts of fertilizer (average 18 kg N ha⁻¹) to growing plants. This low rate is on the steep part of plant response to N curve and should serve to enhance efficiency; plant growth, however, is generally stunted in Malawi due to degraded soils and weed competition. Very limited crop yields reduce N efficiency from a simulated 60 kg grain per kg N to an actual of ~20 kg grain per kg N (at 40 kg N ha⁻¹ applied). Legume-intensified systems could improve growth potential and restore N use efficiency through amelioration of soil quality and transfer functions and from biological fixation N inputs. In the Michigan system, N efficiency is enhanced currently through multiple, split applications of N fertilizer tailored to plant growth rate and demand. Fertilizer N rates used by growers, however, averaged 32% higher than recommended rates and 40% higher than N removed in crop product. Application of 50 kg N ha⁻¹ to cover crops in the fall may contribute to the apparent high potential for N leaching losses. Careful consideration of credits from legumes and residual soil N would improve N efficiency. Overall, N budgets indicated 0 to 20 kg N ha⁻¹ loss potential from the Malawi systems and tenfold higher loss potential from current practice in Michigan maize/potato rotations.

Best management practices, with or without integration of legumes, could potentially reduce N losses in Michigan to a more acceptable level of about 40 kg N ha⁻¹.

Citation: Snapp S.S, Borden H and Rohrbach D, (2001). Improving Nitrogen Efficiency: Lessons from Malawi and Michigan, *The Scientific World* 1(S2), pp. 42–48

3.6 Modeling the fluxes of nitrogen, phosphate and sediments in Linthipe catchment, Southern Lake Malawi Basin: Implications for catchment management

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This study was carried out to investigate the fluxes of nutrients and sediments in Linthipe River catchment of Lake Malawi basin and the manner in which it is affected by anthropogenic activities and natural processes. Data on climate, nutrients, land use, soil and hydrology were collected to model fluxes of nutrients and sediments using the generalized watershed loading function (GWLF) model. The correlation coefficient (r²) derived from comparing the observed and simulated river discharge was 0.92. For sediments, total nitrogen and total phosphorus, comparison of predicted values with observed data were not statistically significant. The data was also used to model hypothetical management scenarios. A hypothetical 10% deforestation of the catchment may lead to an increase in annual sediment, nitrogen and phosphorus loads by 27.1, 15.7 and 2.9%, respectively. The GWLF approach overall appears to provide reasonably good estimates of mean annual sediment and nutrient loads. Results from this study suggest that anthropogenic activities (agriculture and deforestation) may be by far the largest source of sediment and nutrient loading especially during the rainy season.

Citation: Goman MC, Valeta J and Phiri S.J.K.S, (2010). Modeling the fluxes of nitrogen, phosphate and sediments in Linthipe catchment, Southern Lake Malawi Basin: Implications for catchment management, *African Journal of Agricultural Research* Vol. 5 (6), pp. 424-430

3.7 Nitrogen dynamics in cropping systems in southern Malawi containing *Gliricidia sepium*, pigeonpea and maize

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This study tested the hypothesis that incorporation of green leaf manure (GLM) from leguminous trees into agroforestry systems may provide a substitute for inorganic N fertilisers to enhance crop growth and yield. Temporal and spatial changes in soil nitrogen availability and use were monitored for various cropping systems in southern Malawi. These included *Gliricidia sepium* (Jacq.) Walp. trees intercropped with maize (*Zea mays* L.), with and without pigeonpea (*Cajanus cajan* L.), sole maize, sole pigeonpea, sole gliricidia and a maize + pigeonpea intercrop. Soil mineral N was determined before and during the 1997/1998, 1998/1999 and 1999/2000 cropping seasons. Total soil mineral N content (NO₃⁻ + NH₄⁺) was greatest in the agroforestry systems (p<0.01). Pre-season soil mineral N content in the 0–20 cm horizon was greater in treatments containing trees (185 kg N ha⁻¹) than in those without (<60 kg ha⁻¹; p<0.01); however, soil mineral N content declined rapidly during the cropping season. Uptake of N was substantially greater in the agroforestry systems (200–270 kg N ha⁻¹) than in the maize + pigeonpea and sole maize treatments (40–95 kg N ha⁻¹; p<0.01). Accumulation of N by maize was greater in the agroforestry systems than in sole maize and maize + pigeonpea (p<0.01); grain accounted for 55% of N uptake by maize in the agroforestry systems, compared to 41–47% in sole maize and maize + pigeonpea. The agroforestry systems enhanced soil fertility because mineralisation of the applied GLM increased pre-season soil mineral N content. However, this could not be fully utilised as soil N declined rapidly at a time when maize was too small to act as a major sink for N. Methods for reducing losses of mineral N released from GLM are therefore required to enhance N availability during the later stages of the season when crop requirements are greatest. Soil mineral N levels and maize yields were similar in the gliricidia + maize and gliricidia + maize + pigeonpea treatments, implying that addition of pigeonpea to the tree-based system provided no additional improvement in soil fertility.

Citation: Chirwa PW, Black CR, Ong CK and Maghembe J, (2006). Nitrogen dynamics in cropping systems in southern Malawi containing *Gliricidia sepium*, pigeonpea and maize, *Agroforestry Systems journal* 67, pp. 93-106

3.8 Role of herbicide (metalachlor) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi

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The parasitic weed species *Striga asiatica* (L.) Kuntze is one of the major constraints in maize production in Malawi. The effects of metalachlor (as Dual TM Magnum 960 EC), a pre-emergence herbicide, with 69N:21:P2O5:4S kg ha⁻¹ and without fertilizer application, on maize growth and *Striga* suppression, were investigated at 5 sites in 2000/01 season and 6 sites in 2001/02. The use of metalachlor at 2.2 kg ha⁻¹ gave no considerable phytotoxic effects on maize plants. Application of metalachlor significantly suppressed *Striga* emergence across all sites in 2000/01 and not in 2001/02. Metalachlor application increased yields from 1448 to 1793 kg ha⁻¹ in 2000/01, and from 1677 to 2077 kg ha⁻¹ in 2001/02. On the overall, the use of fertilizer was superior to herbicide use in increasing maize yields. Yields were generally low as, in most cases, sites with *Striga* are low in productivity. Due to this association between poor site productivity and *Striga*, an integrated approach which tackles both problems is suggested. For example, rotation with legumes is strongly recommended not only to reduce *Striga* seeds in the soil, but to improve fertility. The increased productivity in subsequent years would then allow sufficient yields to cover other inputs such as herbicides, fertilizer and improved seed.

Citation: Kabambe VH, Kauwa AE and Nambuzi SC (2008). Role of herbicide (metalachlor) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi, African Journal of Agricultural Research 3 (2):140-146

3.9 Farmer evaluation of phosphorus fertilizer application to annual legumes in Chisepo, Central Malawi

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Building from the perception that farmers have an intimate knowledge of their local environment, production problems, crop priorities and criteria for evaluation, an on-farm experiment was conducted with farmers in 2003/4 in Chisepo, central Malawi, to evaluate the response of six annual legumes to phosphorus (P) (20 kg P ha⁻¹ or no P fertilizer) application. The legumes were velvet bean, pigeonpea, soybean, groundnut, bunch-type cowpea and Bambara groundnut. Twelve farmers hosted the experiments and each farmer formed a group of at least 4 other farmers to evaluate the legumes. Farmer participatory monitoring and evaluation of the legume and P combinations was conducted during the experiment to determine farmer preferences and acceptance of the technology. Measured grain yields, returns to labour and total costs of the P-fertilized legumes were compared with those for the unfertilized legumes. The application of P fertilizer significantly ($P = 0.05$) increased legume grain yields, particularly with velvet bean, and soybean. However, use of P was not financially attractive and farmers were not interested to use P at the time. Farmers were more interested to maximize legume food production from their labour investment. Soybean, groundnut and pigeonpea, grain legumes with high value as food, were considered to be priority crops by farmers over velvet bean, cowpea and Bambara groundnut

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3.10 Synergistic effect of inorganic N and P fertilizers and Organic inputs from *Gliricidia sepium* on productivity of intercropped maize in Southern Malawi

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In Malawi, N and P deficiencies have been identified as major soil fertility constraints to maize (*Zea mays*, hybrid NSCM 41) productivity. In this study, we evaluated the effect of three rates of N and P fertilizers on maize performance in monoculture and maize intercropped with the nitrogen fixing legume *gliricidia* (*Gliricidia sepium*) in replicated field trials run for four years (2002/03-2005/06 seasons) at Makoka, in southern Malawi. Significant season-to-season variation was found in stand loss, ears per plant, stover yield, grain yield and thousand kernel weight (TKW), which was related to distribution of rainfall received during the growing season. All variables were significantly higher in the *gliricidia*/maize intercrop compared with monoculture maize. During the four

consecutive cropping seasons, grain yields of maize increased by 343% (i.e. from 0.94 tons ha⁻¹ in unfertilized sole maize to 4.17 tons ha⁻¹ in gliricidia/maize intercropping). Optimum synergistic effect on grain yield (38% increase over unfertilized gliricidia/maize) was obtained when half recommended N and P rates were combined with gliricidia indicating interspecific facilitation. Response surface modelling showed that the optimum combination of factors for maximum grain yield (4.2 t ha⁻¹) in monoculture maize was 80 kg N ha⁻¹, 31 kg P ha⁻¹ and 917 mm seasonal rainfall. In the gliricidia/maize intercrop, the stationary point had no unique maximum. Ridge analysis revealed that the estimated ridge of maximum grain yield (5.7 t ha⁻¹) in the intercrop is when 69 kg N ha⁻¹, 37 kg P ha⁻¹ is applied and a seasonal rainfall of 977 mm is received. The total P uptake in the intercrop (14.3 kg ha⁻¹) was significantly higher than that in maize monoculture (6.6 kg ha⁻¹). P uptake was significantly (P = 0.008) influenced by P fertilizer rate. Therefore, we conclude that combining inorganic N and P fertilizers with organic inputs from Gliricidia has positive and synergistic effects on maize productivity in southern Malawi.

Citation: Akinnifesi F, Makumba W, Sileshi G, Ajayi O.C and Mweta D, (2007). Synergistic effect of inorganic N and P fertilizers and Organic inputs from Gliricidia sepium on productivity of intercropped maize in Southern Malawi, *Plant Soil* 294, pp. 203–217

3.11 Pigeon pea phosphorus micro dosing trial

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An experiment was initiated in 2011-12 cropping season to improve soil fertility in central region through testing the suitability of medium duration pigeon pea varieties at three different rates of micro doses of phosphorus from phosphorus based fertilizer. The objective of the trial was to evaluate the effects of micro dosing phosphorus on a medium and long duration pigeon pea crop varieties on biological and economical yield. A 2 x 4 factorial experimental design replicated three times to evaluate factors under study. One medium duration pigeon pea crop variety (ICEAP 0557) and a long duration pigeon pea crop variety (ICEAP 0040) were evaluated against four levels of phosphorus; of 0, 10, 15 and 20 Kg P/ha. The trial was conducted in NASFAM project sites located in Lilongwe, Salima and Kasungu districts with some replication at research stations. Biological and economic data was collected and analyzed. Soil data was not included because it was already reported in the first season of this study. Genstat version 7.0 was used to analyze data collected. Results indicate No significant differences (p=0.05) were observed on biological and economical yield due to the influence of factors under study. However significant differences (p=0.05) were observed on the interaction between pigeon pea varieties and phosphorus levels

Citation: Kamalongo D, Ngwira AR, Ligowe IM, Siambi M, Madzonga O and Kabambe VH (2015). Pigeon pea phosphorus micro dosing trial, *Soils and Agricultural Engineering commodity group project reports (2014/15) and proposals for (2015/16)*, Department of Agricultural Research Services, Lilongwe, Malawi

3.12 On-farm verification of outstanding drought and low nitrogen tolerant varieties using the mother-baby trial approach

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Low or decline soil fertility and recurrent droughts among others are the remarkable factors limiting maize production and consequently household food security in Malawi. During 2011-12 cropping season, twelve improved maize varieties tolerant to low N and drought conditions were in stress environments of low and mid altitudes of Malawi. Maize varieties tested were: C 586-13, ZM 725, C 586-1, MH 27, CZH 0948, C530-6, CZH 1036, CZH 0819, MAO 7003, MH 26, ZM 625 and ZM 627. A mother baby approach scheme was used to evaluate these varieties. A randomized complete block design replicated three times was used. Maize varieties were evaluated at two soil fertility management levels namely: recommended fertilizer application of 92kg N ha⁻¹ termed as green trial and at half fertilizer recommended rate termed as yellow trial. Significant differences (p=0.05) due to site differences were observed. No significant differences across fertilizer levels were observed among maize varieties tested. Under yellow fertility levels, the following maize varieties emerged highest: MH 26, CZH 0819 and MAO 7003. Under green fertility the following maize varieties gave higher yields over or equal to the check: MH 26, CZH 0819 and MAO 7003. Farmers towards choice of a variety were also evaluated. Farmers preferred varieties with the following trait: milling quality, drought tolerance, cob size and yield. Weevil resistance, cob rots and grain colour were not considered an important trait by farmers.

Citation: Kamalongo D, Ligowe IM, Ngwira AR, Mwale CD, Kabambe VH and Kaonga KKE. (2015). On-farm verification of outstanding drought and low nitrogen tolerant varieties using the mother-baby trial approach, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

3.13 Enhanced resilience to seasonal dry spells in rainfed maize, and upland rice using silicon based fertilizer

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The problem is that there is a generally observed change in rainfall patterns in Zambia and Malawi, with delayed start, prolonged within season dry spells, and early ending of season. This affects productivity and yield due to delayed planting, poor crop establishment and increased pest incidences. There is need to develop mitigation strategies that will enhance resilience to these conditions. Silicon (Si) has been found to improve drought resilience in crops through formation of an opal layer in the leaf structure that reduces transpiration during water stress. This research and development study will aim at identifying locally available sources of Si; experiment with ways of enhancing bioavailability of Si; and test the effect of different formulations of Si based fertilizer on drought resilience in maize and upland rice. The target is small scale farmers practicing rain-fed conservation agriculture that includes maize, and upland rice crops. The study fits well with the APPSA medium priority area 5: research on technology for adaptation to climate change. The expected outcome is improved access to Si fertilizer technology among target farmers resulting in improved resilience to seasonal droughts and dry spells in rain-fed maize and upland rice systems. The expected impact will be improved productivity in rain-fed production systems in Zambia and Malawi, contributing to the overall APPSA goal of improving household food and nutrition security and incomes in of smallholder producers. The R and D project will be conducted as a partnership between Mulungushi University and Chitedze Agricultural Research Station (Malawi). The project will also involve consultants from industry, Si Technologies B.V. and from other government agencies, ZARI, Geologic Survey Unit, and National Remote Sensing Centre. It will be conducted from 2014 to 2017 and will involve desk/internet study; greenhouse experiments; field trials; and field demonstrations to develop an affordable Si based fertilizer and test its effect on drought resilience in rain-fed, small holder crop production system

Citation: Munsanje K and Munthali C (2015). Enhanced resilience to seasonal dry spells in rainfed maize, and upland rice using silicon based fertilizer, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

3.14 Evaluation of the rhizobium inoculants produced by agri-input suppliers limited (AISL)

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Biological Nitrogen Fixation (BNF) often increases legume yields through inoculation. However, response to inoculation mostly depends on the quality of the inoculant used, soil quality and climate. Laboratory and field experiments were therefore conducted to establish the viability of Nitrofix and assess the ability of these inoculants to produce effective nodules that fix nitrogen on the roots of host plants. Rhizobium population count test results indicate that Nitrofix and USDA110 inoculants had a mean of 3.85×10^8 CFU/g and 2.7×10^8 CFU/g of inoculant material respectively. Both inoculants were above the minimum required level of 1×10^8 CFU for inoculants. In the field trial, the results indicated no significant differences in plant height, root length and indicators of N fixation such as number of pink nodules, root dry weight and shoot dry weight. However, Nitrofix (1.73kg/ha) produced more yields than the control (1.51kg/ha) and slightly lower than the standard USDA110 (1.93kg/ha) which was comparable to the fertilizer (2.05kg/ha). Nitrofix inoculants are therefore able to meet the required international standards.

Citation: Liwimbi LCS, Mtefa J, Kawonga A and Lundu Y (2015). Evaluation of the rhizobium inoculants produced by agri-input suppliers limited (AISL), Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

3.15 Increase productivity of soybeans through enhanced use of rhizobium inoculants

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Increased inoculant use is expected to enhance soybean yield per hectare and biological nitrogen fixation hence effectively reducing inorganic input requirements. This may be achieved through three specific objectives which include establishment of a cultural collection of rhizobium germplasm from Malawi soils, enhanced use of effective strains in inoculant production and increased availability of effective inoculants to smallholder farmers. A total of 50 soil samples each were collected from Mkanda, Chulu and Malomo EPAs in Mchinji, Kasungu and Ntchisi districts respectively. Soybeans were planted in each of the 150 soil samples in replicate. A total of 596 rhizobia bacteria isolates were obtained from the 750 nodules collected from soybean plants in the 150 glasshouse rhizobium soil trials established. Out of these, 492 isolates have been partially characterised due to some challenges ranging from power outage and scarcity of chemicals. It can be concluded that despite the challenges encounter, the project is still progressing fairly well at a pace that will be able to achieve the intended project objectives. However due to the time lost for screening, selection and authentication as well as synchrony of activities, there is need for great improvement.

Citation: L.C.S, Mwafulirwa S and Phiphira L. (2015). Increase productivity of soybeans through enhanced use of rhizobium inoculants, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

3.16 Bioassays of some economic crops of Malawi for *Striga asiatica* seed germination stimulation before and after interaction with the soil

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Root exudate bioassay studies were conducted to assess *S. asiatica* seed germination induction by some crop species before and after interaction with the soil. The double-pot technique for the germination tests, and germinations were compared to those of maize. Germination % of *Striga* ranged from 35-50% for cotton (*Gossypium* spp.), 45-55% for sunflower (*Helianthus annuum*), 45-49 for maize inbreds, and was 53, 41 and 23 % for single entries for sunhemp (*Crotalaria juncea*, velvet beans (*Mucuna puriens*) and dolichos beans (*Dolichos lab lab*). The germination of mize controls ranged 45-56%. In a greenhouse study some varieties of cotton, sunflower, and groundnuts were grown in the *Striga* infested soils for 121 days, and then followed by maize. *Striga* emergence numbers on maize in the second season were used as indicators for the effectiveness of the trap crops. Results showed that in all crop species some varieties were more effective than others. The treatments with lower *Striga* numbers had few flowered *Striga*. The highest *Striga* emergence was on maize after a fallow (bank) treatment, with 27 *Striga* plants pot-1 and ground nuts entry Mawanga (20 *Striga* plants pot-1) while the least was on maize after maize (no *Striga* plant). There was no significant correlation between germination stimulation by the various entries and *Striga* emergence on maize grown after each of them. It is concluded while variations in *Striga* seed stimulation activities exist within crop species, identification of most effective trap crop must be after interaction with the soil. Maize (host crop) could be a very effective trap crop if witchweed is stopped from re-seeding.

Citation: Kabambe VH and Drennan DSH, (2005). Bioassays of some economic crops of Malawi for *Striga asiatica* seed germination stimulation before and after interaction with the soil. In: Safalaoh A.C.L, Gowela J.P and Mtwthiwa A.H.N, editors. Proceedings of the 2nd Bunda College research dissemination conference, Bunda College of Agriculture, Lilongwe, Malawi, pp. 28-33, 2005

3.17 Interaction between residues of maize and pigeonpea and mineral N fertilizer during decomposition and N mineralization

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Nitrogen mineralization patterns of maize and pigeonpea (*Cajanus cajan*) residues were examined in leaching tubes, both in isolation and mixtures, in Malawian soils of varying texture. Senesced pigeonpea leaves (C-to N ratio 24) induced a short period of nitrogen immobilization which was followed by steady nitrogen mineralization in all three soils. The immobilization period lasted between 14 and 28 days and was longer in soils with larger clay contents. Maize residues contained 30% of their N in the form of water-soluble nitrate.

Both the sole maize residue (C-to-N ratio 75 after adjustment for nitrate which constituted 28 % of the N) and the mixture of maize and senesced pigeonpea leaves revealed a similar prolonged strong net N immobilization up to 130 days before the two treatments started to diverge slightly. Mixing maize with pigeon peas residues with equal amounts of N failed to substantially alleviate the N immobilization capacity of the maize residues. N immobilization in the mixture was much greater than that predicted from the mineralization patterns of individual patterns. When increasing amounts (50, 100 and 150 mg N kg⁻¹) of green pigeonpea leaves, senesced pigeonpea leaves and ammonia-N were added to 50 mg N kg⁻¹ soil of maize residues, N released in the mixtures increased with the increasing amount of N added to maize residues with greater increases from residues with larger N concentrations. There was evidence that microbial degradation of maize carbon was limited by N availability. The implications of the results for management of crop residues and mineral N fertilizers in the field are discussed.

Citation; Sakala WD, Cadisch G and Giller KE. (2000). Interaction between residues of maize and pigeonpea and mineral N fertilizer during decomposition and N mineralization, *Soil Biology and Biochemistry* 32 pp. 629-638

3.18 Response of common beans and influence of growth habit when inoculated with different rhizobium strains

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Production of common beans is limited by nitrogen despite its ability to enter in association with nitrogen fixing symbionts. Most of the indigenous strains of Rhizobium which nodulate common beans are poor in nitrogen fixation. Nodulation and nitrogen fixation abilities of climbing beans varieties are also consistently superior to most bush varieties. This study was conducted on station at Chitedze, Bvumbwe, and Bembeke to determine the performance of common bean lines when inoculated with different strains of rhizobium and determine the effect of botanic group of common bean lines (dwarf and climbers) when inoculated with different types of rhizobium strains. The results show that botanic group and type of variety had an influence on the performance of common beans in term of nodule score, plant height, fresh weight, dry weight and grain yield. Generally, the type of strain and their interactions with botanic groups or genotype had no significant effect on most of the parameters except for the type of strain at Chitedze on fresh weight and Bembeke on plant height. Out of the three strains being evaluated, no strain was established as either superior or inferior to the other.

Citation: Chirwa R.M and Liwimbi LCS (undated). Response of common beans and influence of growth habit when inoculated with different rhizobium strains. Technical Report, CIAT, Lilongwe, Malawi

3.19 Improving Nitrogen efficiency: Lesson from Malawi and Michigan

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Two case studies are presented on nitrogen (N) dynamics in potato/maize systems. Contrasting systems were investigated from (1) the highland tropics of Dedza, Malawi in southern Africa and (2) the northern temperate Great Lake region of Michigan. Formal surveys were conducted to document grower perceptions and management strategies. Survey data were linked with N budgets conducted by reviewing on-farm data from representative farms in the targeted agro-ecosystems and stimulation modeling to estimate N losses. The Malawi systems uses targeted application of small amount of fertilizer (average kg N ha⁻¹) to growing plants. This low rate is on the steep part of plant response to N curve and should serve to enhance efficiency; plant growth, however, is generally stunted in Malawi due to degraded soils and weed competition. Very limited crop yields reduce N efficiency from a stimulated 60 kg grain per kg N to an actual of ~20kg grain per kg N (at 40 kg N ha⁻¹ applied). Legume-intensified could improve growth potential and restore N use efficiency through amelioration of soil quality and transfer function and from Biological Nitrogen Fixation N inputs. In the Michigan system, N efficiency is currently enhanced through multiple, split application of fertilizer tailored to plant growth rate and demand. Fertilizer N rare used by growers, however, averaged 32% higher than recommended rates and 40 % higher than removed in crop product. Application of 50kgN ha⁻¹ to cover crops in the fall may contribute to the apparent high potential for N leaching losses. Careful consideration of N credits from legumes and residual soil N would improve N efficiency. Overall, N budgets indicated 0 to 20 kg N ha⁻¹ loss potential from current practice in Michigan maize/potato rotations. Best management practices, with or without integration of legumes, could potentially reduce N losses in Michigan to a more acceptable level of about 40 kg N ha⁻¹

Citation:Snapp SS, Borden H and Rohrbach D (2001). Improving Nitrogen efficiency: lesson from Malawi and Michigan, *The Scientific World* 1(S2), pp. 42-48

3.20 Phosphorus, sulphur and molybdenum effects on response of Phaselous beans to inoculation with rhizobium in Malawi

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The effects of P, S and Mo on the response of fields beans (*Phaseolus vulgaris* L.) to inoculation with *Rhizobium leguminosarum* bv. *Phaseoli* were investigated at four sites in Malawi. Treatments consisted of non-inoculation and inoculation; fertilization at 0 and 17.5 kg P ha⁻¹; 0 and 30 kg S ha⁻¹; and 0 and 1kg Mo ha⁻¹. A nitrogen control at 100 kg N ha⁻¹ was included. To identify the nutrients that limited response to inoculation most P, S and Mo were either applied or not applied to the inoculated plants. At all study sites, there was no significant response ($P > 0.05$) of nodule number to inoculation. Grain yield increased by 39 % due to inoculation at Champhira. Improved soil fertility increased nodule number 387 to 426% at three sites of the four sites. At least one of the three nutrients was identified as limiting nodulation at eac site, but grain yield were only affected by P deficiency at Sokola and Mo at Champhira. Therefore, alleviating nutrient and increasing nodule occupies the deficient inoculant strains are some of the ways in which the response of beans to inoculation could be increased.

Citation: Lupwayi NZ and Mkandawire ABC. (1996). Phosphorus, sulphur and molybdenum effects on response of Phaselous beans to inoculation with rhizobium in Malawi, *African Crop Science Journal* 4(3), pp. 359-364

3.21 Sulphur nutrition of maize in four regions of Malawi

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Sulphur, though widely deficient in Africa, has received little attention by soil fertility researchers. Shifts to low-S, high analysis fertilizers, continuous cropping, and higher yielding varieties may have increased S limitations in maize (*Zea mays*) production. We aimed to characterize maize S nutritional status in farmers' field in four regions on Malawi and determine the response of maize to S. Four 42 to 68 km² study areas were delineated, two with low elevation lacustrine soils, and two with highly weathered residual upland soils. Maize plants in 238 farmer field were sampled for nutrient analysis at 8 to 12 leaf vegetable and tasseling growth stages. Replicated experiments were conducted in two years on a total of 20 farms to determine maize response to S with or without N and/or P. sampling areas differed significantly in maize S concentrations, S diagnosis and Recommendation Integrated System (DRIS) indices, and N: S ratio, 11.5. The ration of N:S in the aerleaf was the best predictor p of maize yield response to S ($R^2=0.58$). Maize yields showed an N x S interaction such that there were no responses to S unless N was also supplied. With 80kg/ha N, a significant response to S was shown by maize in all but one of 20 experiments. A response curve for S showed that 5 to 10kg/ha of S was optimal, with mean yield responses ranging from 90 to 142 kg grain/kg S.

Citation: Weil RR and Mughogho SK (2000). Sulphur nutrition of maize in four regions of Malawi, *Agronomy Journal* 92: 649-656.

3.22 Soil acidity and ameriorative measures in Malawi

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Most upland soil in Malawi are highly weathered, low in soil pH and deficient in most soil nutrients, over 40% of Malawi soils have a pH of less than 5.5 (in water) and it is recommended that liming should be applied when the pH is less than 5.5. Malawi has large deposits of limestone (dolomite and calcite) and the use of dolomite to amend for soil acidity will in addition supply calcium and magnesium to the crop. Due to the need to increase maize yields in acid soils, liming experiment were conducted in Dedza (Bembeke and Kanyama), Ntheu (Tsanganano) and Mangochi (Katuli). Dolomite lime was used and the rates used were 0, 1000, 2000, 4000 and 8000kg/ha. Complete Block Design with four replicates was used. Lime incorporation was broadcasted and incorporated into the soil. Fertilizer was applied as recommended in the country. The results showed that liming significantly increased grain yield and 2000 dolomitic lime per hectare was the most optimum rate of application and the gross margin was the highest at this rate as well. The liming also increased rooting depth of maize crop. It is recommended that 2000kg/ha should be applied every four years

Citation: Chilimba A.D.C (undated). Soil acidity and ameriorative measures in Malawi, Technical Report, Chitedze Agricultural Research Station , Lilongwe, and Malawi

3.23 Rhizobial inoculation and P fertilizer response of common beans (*Phaseolus vulgaris*) under field conditions

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Osmotic constraints, nutrient deficiencies, especially phosphorus and lack of strains of rhizobia are important factors limiting symbiotic fixation and yield in common bean. Nitrogen fixation in common beans is mostly affected by P deficiency than other legume crops such as soybean. The study was conducted on station at Bvumbwe to determine the response of common beans in soils with low and adequate levels of Phosphorus and determine the response of common beans to inoculations to conditions above. The soil had low N (0.08%) and low P (12µg/g of soil). The addition of P to the soil resulted in reduction of chlorophyll as well as transpiration rate and an increase in the number of pods, plant height, grain yield and both leaf and stem dry weight. Inoculation reduced chlorophyll level and increased transpiration rate under low P. Plant height and grain yield increased with an increase in plots where P was added. Inoculation had no effect on the number of pods and both leaf and stem dry weight (biomass) of the plants. The results show that response to inoculation was better in the soil environment where levels of phosphorus are adequate.

Citation: Chirwa RM and Liwimbi LCM (undated). Rhizobial inoculation and P fertilizer response of common beans (*Phaseolus vulgaris*) under field conditions, Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

3.24 Evaluation of the rhizobium inoculant from Chitedze Production Unit

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Biological nitrogen fixation process through inoculation has greatly increased legume yields in many areas. However, response of legumes to inoculation depends on the quality of the inoculants used. Laboratory and green house tests were conducted to evaluate the rhizobium inoculants from Chitedze Agricultural Production unit. Assess the ability of these inoculants in fixing nitrogen. Rhizobium population result had a mean of 1.02×10^{10} CFU/g of inoculant material which was above the minimum level of cell required. An average of 29.2 nodules having a pink/red inside was established in a nitrogen free solution indicating that the cells were both infective and effective. Under the soil environment, the competition from the indigenous rhizobia strains was high even though the treated pots had significant greater number of nodules than the control. Chitedze inoculants are able to meet the required international standards although the responses may be masked by some other soil factors

Citation: L.C.S Liwimbi, J Mtefa, A. Kawonga and Y. Lungu, (2015). Evaluation of the rhizobium inoculant from Chitedze Production Unit, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

3.24 Evaluation of the use of herbicide (Imazapyr) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi

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The parasitic weed species *Striga asiatica* (L.) Kuntze is one of major constraints in maize production in Malawi. Studies were conducted from 1999/2000 to 2001/2002 seasons to evaluate the effects of seed dressing with imazapyr (an acetolactate synthase [ALS] - inhibiting herbicide) at 0 and 45 g ha⁻¹ and two fertilizer rates (0 and 69N:21P2O5:0+4S kg ha⁻¹) on maize with ALS target site resistance on *Striga* suppression and grain yield at Chitedze Research Station and farmers' fields. In the first season, imazapyr suppressed *Striga* emergence across all sites but did not increase yield. In contrast, fertilizer application had no effect on *Striga* emergence ($P > 0.05$), but significantly increased yield ($P < 0.05$). In the second season results were similar, but in addition the use of herbicide increased yield. In the third season a local hybrid (SC627) was included to compare yield potential of the untreated Imazapyr Resistant (IR) variety. The local check yielded higher than the IR hybrid with or without herbicide treatment, but sustained the highest emergence of witchweeds. The untreated IR hybrid had less *Striga* than SC627 and more than the treated. Overall, fertilizer use is found to be the single most important factor in increasing maize yield under *S. asiatica* infection, while herbicide use is important for reducing emergence.

Citation: Kabambe VH, Kanampiu F, Nambuzi SC and Kauwa AE (2007). Evaluation of the use of herbicide (Imazapyr) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi, African Journal of Agricultural Research 2 (12): 687-691.

3.25 The role of integrated soil fertility management on field insect pest of crops: Review paper

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Integrated soil fertility management (ISFM) is being promoted worldwide soil improvement and subsequent crop yield increases. ISFM is defined as a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt to these conditions to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving productivity. Many insect seeks high nitrogen sources to meet their nitrogen requirement. Insect herbivores response to various levels of plant N depends on insect species concerned, more especially that different species contain varying levels of N in their bodies. Interaction between nitrogen contents of plants and population dynamics of herbivores are complex. This paper reviews studies on insect herbivore response to synthetic fertilizers, organic manures, combination of organic and synthetic fertilizers. The predator parasitoid response in such ecosystem is also reviewed.

Citation: Tembo Y, (2014). The role of integrated soil fertility management on field insect pest of crops, In: Kabambe V, Tembo Y and Ngwira A., eds Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 123-128



Part 4: The Use of Organic and Inorganic Fertilizers

4.1 Use of pruning and mineral fertilizer affects soil phosphorus availability and fractionation in a gliricidia/maize intercropping system

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Leguminous tree species are known to replenish soil nutrients through biological N fixation, mulch effect and recycling of other nutrients from the deeper soil layer to the topsoil, when managed in agroforestry systems. The soil available phosphorus (P) status and inorganic P-forms (fractionation) in a long-term gliricidia-maize trial was studied to understand the effect of additions of Gliricidia prunings combined with and without inorganic fertilizers (N and P). Addition of gliricidia prunings and inorganic N and P fertilizers significantly increased phosphorus uptake by maize. Bray P1 had strong correlation with P uptake by maize in gliricidia/maize intercropping ($r = 0.81$, $p < 0.001$). Both the Olsen and Bray P1 methods of extraction were strongly correlated ($r = 0.80$). Phosphorus fractionation data of the soils from the maize and gliricidia-maize plots indicated that the Fe-P fraction was the most dominant form of inorganic P. The addition of gliricidia prunings significantly reduced the Fe-P and Al-P forms. We conclude that iron phosphate acts as a sink for applied inorganic P in Lixisols and the increased soil organic matter through addition of gliricidia prunings solubilizes fixed P in the soil.

Citation: Mweta DE, Akinnifesi FK, Saka JDK, Makumba W and Chokotho N (2007). Use of pruning and mineral fertilizer affects soil phosphorus availability and fractionation in a gliricidia/maize intercropping system. *African Journal of Agricultural Research* 2 (10): 521-527.

4.2 Minimum rates of *Tithonia diversifolia* for integration with inorganic fertilizers

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A trial was conducted during the 1998/99 season on farm at Mulangeni, Bembeke, Chitedze and Champhira and Bembeke station. The objectives of the trial were (a) to compare the maize yield benefits of *Tithonia* to inorganic fertilizers and (b) to establish whether low rates of *Tithonia* with inorganic fertilizers are more effective than either input separately. The results have shown that application of *Tithonia* leaves at 3t/ha to 7t/ha with or without inorganic fertilizer were significantly different from the control. Application of *Tithonia* leaves alone produced similar yields as to when integrated with inorganic fertilizers. Across sites averages showed that with the application of *Tithonia* biomass alone, maize yield ranges from 2869 to 3037 kg/ha. This confirms earlier results that *Tithonia* can produce equally high yields when used alone without inorganic fertilizers. However, maize yields from Bembeke, Mulangeni and Champhira were low because the maize was attacked by gray leaf spot otherwise yields would have been much higher

Citation: Ganunga RP, Kabambe VH, Kumwenda JDT and Thangata MG (2001). Minimum rates of *Tithonia diversifolia* for integration with inorganic fertilizers, Maize Commodity Team Annual Report for the 1998/99 growing season, Department of Agricultural Research Services, Lilongwe, Malawi

4.3 Effect of organic quality on N fertilizer use efficiency

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An investigation was initiated to quantify the effect of organic residue quality, amount and application method on N fertilizer efficiency in maize based cropping system in the unimodal rainfall areas of Southern Africa. The influence of high quality organics on N dynamics, and in particular, the interaction of organic and inorganic of nutrients sources in the sub-humid tropics is not well understood. It is known that nitrogen immobilization occurs if low quality, wide C: N ratio and high lignin residues are added to soil. In contrast, high quality organic materials from leguminous trees with a narrow C: N ratio and high levels of soluble substrate are predicted to enhance microbial biomass and activity. Enhanced microbial activity associated with a small but rapidly turning over inorganic N pool. This is hypothesized to reduce the amount of N that can be leached and improve synchrony of N supply to the growing crop thus enhancing N fertilizer efficiency. Two separate field experiments were conducted over two seasons.

In experiment one, leaf residues of *Grilicidia sepium* were compared to that of *Leuceana leucocephala* at two application rates using different application methods with or without N fertilizer. In experiment two, leaf residues of *Tephrosia vogelii* were compared to that of *leuceana leucocephala* using two application methods. Residues were applied once at the beginning of the first season in both experiments. Quality of residues was quantified by measuring the content of N, lignin content and polyphenolics. *Tephrosia* and *Grilicidia* were superior to *Leucaena* in both experiments. In experiment one, the following interaction were significant: season x residue quality x N fertilizer, season x residues application method and residue application rate x N fertilizer. In experiment two, there was a significant season x residue application method interaction application. The results indicate nutrients were rapidly released from residues of all species but that there was a strong residual effect on maize yields in the second year. Farther research on N dynamics will clarify N fertilizer and residue quality interactions.

Citation: Jones RB, Snapp SS and Phombeya HSK, (1995). Effect of organic quality on N fertilizer use efficiency, a paper presented at the conference driven by nature of litter quality and decomposition on 17-20 September, 1995, Wye University, UK

4.4 Evaluation of agronomic management of leaf litter and inorganic fertilizer on maize (*Zea mays* L.) grown after a two-year pigeonpea (*Cajanus cajanus*) fallow in Malawi

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In Malawi maize is a staple food crop and poor soil fertility is one of the main challenges in its production. Organic sources of fertility amendments are usually available to farmers in different forms and quantities, however, current recommendations only provide guidelines for management of organic and inorganic management separately without guidelines for context specific management. A study was conducted at Bunda College of Agriculture (14° 35' S and 33° 50' E, 1031 masl) in the 2007/08 season to evaluate the effects of some management options for organic and inorganic fertilizer additions on land grown to a two-year pigeon pea fallow. A factorial experiment with pigeon pea residue management (RM1 = surface vs RM 2 = incorporation) and inorganic fertilizer packages management (FP1= 0 kg/ha fertilizer; FP2 = 23:21:0+4S(kg/ha N:P2O5:K2O) as basal dressing; FP3=46:21:0+4S as basal and top-dressing; FP4 = 46:0:0 as top-dressing; and FP5= 92:21:0+4S) were super-imposed. The estimated leaf litter (no twigs and stems) at the start of the experiments was 2390 kg/ha dry weight with 2.1 % nitrogen. The results showed no significant RM x FP effects on grain yield, plant height at 6 and 12 weeks after emergence, leaf chlorophyll index, ears per plant and seed weight. There was significantly higher grain yield ($p < 0.05$) with residue incorporation compared to surface placement (5291 vs 4235 kg/ha). The same was true with plant height at 12 weeks, ears per plant, but not plant height at 6 weeks, chlorophyll index, and harvest index. The fertilizer management treatment FP1 was significantly ($p < 0.05$) lower than the other levels (=2858 kg/ha). Amongst treatments with added fertilizer FP gave the lowest yield of 4338 kg/ha, compared to FP3-FP5 which were similar ($P > 0.05$). On the basis of these results, it appears for medium fertilizer application, only applying top dressing N is enough. However, there were responses to if higher rates of up to 92 kg/ha are applied, which still require recommended split applications.

Citation: Sanga F and Kabambe VH (2014). Evaluation of agronomic management of leaf litter and inorganic fertilizer on maize (*Zea mays* L.) grown after a two-year pigeonpea (*Cajanus cajanus*) fallow in Malawi. International Journal of AgriScience 4 (6): 307-312

4.5 Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi

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Loss of soil fertility is one of the major challenges to agricultural production in Malawi, with nitrogen considered the main limiting factor to crop growth. An on-farm study was conducted on an Ultisol in Kasungu district, Central Malawi, to evaluate the effects of sole cropped and doubled-up grain legumes' (legume-legume intercrop) residues and inorganic N supplement on maize yields. Maize was planted in a randomized complete block design experiment where plots were split into different top dressing N fertilizer levels. Results showed that combinations of residues of sole cropped groundnuts with 23 kg N ha⁻¹ and 46 kg N ha⁻¹ inorganic fertilizer top dressings; residues of inoculated sole cropped soybean, sole cropped pigeon pea, and pigeon pea/groundnut intercrop with 46 kg N ha⁻¹ inorganic fertilizer top dressing resulted in maize grain yields of 1942 kg ha⁻¹ and 2152 kg ha⁻¹; 2056 kg ha⁻¹, 1838 kg ha⁻¹, and 1806 kg ha⁻¹ respectively, that were significantly ($p < 0.05$) higher than those from treatments of maize residues with the same rates of inorganic N fertilizer top dressing (maize grain yields of 1174 kg ha⁻¹ and 1569 kg ha⁻¹ respectively).

It was also observed that both sole cropped and doubled-up legume residues with 23 kg N ha⁻¹ and 46 kg N ha⁻¹ inorganic fertilizer produced maize grain yields that were comparable to that produced from a treatment of maize residues supplemented with 92 kg N ha⁻¹. From this study it can be concluded that incorporation of both sole cropped and doubled-up legume residues with a supplement of 23 kg N ha⁻¹ inorganic fertilizer as top dressing in maize production can be a good option for resource poor farmers in Central Malawi and similar agro-ecological zones

Citation: Njira KOW, Nalivata PC, Kanyama-Phiri GY and Lowole MW (2013). Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi. *Agricultural Science Research Journals* 3 (3): 97-106.

4.6 Evaluating the effect of pelletized tobacco waste (PTW) and inorganic fertilization on soil fertility, disease and pest infestation and maize productivity

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Field experiments were conducted at Chitedze and Kandiya Research Stations to evaluate the effect of pelletized tobacco waste (PTW) and inorganic fertilization on soil fertility, disease and pest infestation and maize productivity. Seven treatments were evaluated in a Randomized Complete Block Design with three replications. Treatments included 0 Nitrogen, 100% Inorganic fertilizer, 100% Organic fertilizer (2% N) – leaf mid ribs, 100% Organic fertilizer (1.3% N) – grounded leaf dusts, 75% Inorganic + 25% Organic (2% N), 50% Inorganic + 50% Organic (2% N) and 25% Inorganic + 75% Organic (2% N). All fertilizer treatments supplied 92 kg N/ha as is currently recommended for maize production in Malawi. The hybrid maize variety SC 403 was used in the experiment. The results showed that maize yield was maximum when the plants were fertilized at 92 kg N ha⁻¹ with 23:21:0 for basal dressing and urea as top dressing inorganic fertilizers at both Chitedze and Kandiya. The nil treatment gave the lowest grain yield. Use of PTW only gave higher grain yield over the nil treatment. Combined organic and inorganic fertilizer sources in different proportions, gave higher grain yield over application of PTW only. While as the 75:25 gave comparable yields to the complete inorganic treatment at Kandiya, the 50:50 compared well in yield with the recommended inorganic fertilizer treatment at Chitedze. Treatments had no significant influence on Grey Leaf Spot, but the 25 % inorganic and 75% Organic combination treatment had significantly higher scores of 1.2 and 1.8 for *Exserohilum turcicum* maize disease at Kandiya and Chitedze, respectively.

Citation: Kamalongo D and Munthali FC (2013). Evaluating the effect of pelletized tobacco waste (PTW) and inorganic fertilization on soil fertility, disease and pest infestation and maize productivity, Annual Research Project report for 2011/12 growing seasons, Department of Agricultural Research Services, Ministry of Agriculture and Food Security, Lilongwe, Malawi

4.7 Assessing the effectiveness of integrating home –made fertilizer “combination of ecosystem based fertilizer (biofertiliser) and inorganic fertilizer” for increased maize yield

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Smallholder farming is increasingly forced to meet up growing food needs due to natural population growth. This makes production cost higher due to soil degradation which also comes as a result of increase in inorganic fertilizer which makes environment not favorable for soil fauna. Soil micro/meso/macro fauna are responsible for mobilization, solubilization, mineralization and nitrogen fixation. Environmental and agriculture waste are used in compost making but release less nutrients. Combination of Environmental and agriculture waste and inorganic fertilizer before application can take advantages of both fertilizers hence increasing production while improving soil health. This research study assesses the effectiveness of mixing maize bran (madeya), agroforestry leaves, ash, soil and inorganic fertilizer as an assumption to reduce the production cost and improving soil health

Citation: Mwafulirwa S, Botoman L, Liwimbi L, Katunga A, Chisale M and Njoloma J (2015). Assessing the effectiveness of integrating home –made fertilizer “combination of ecosystem based fertilizer (biofertiliser) and inorganic fertilizer” for increased maize yield, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

4.8 Synergistic effect of composted chicken manure and small dose of inorganic fertilizer in maize production system

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Chicken manure are known to provide high quality ameliorant for soil fertility, however, farmers requires large volume of manure in order to achieve some results as inorganic fertilizers. And on the other hand the later is very expensive and unaffordable by many smallholder farmers in Malawi. A study was conducted at Chitedze Agricultural Research Station to evaluate the synergy of the combination of the composted chicken manure and small dose of inorganic fertilizer. The chicken manure contained 29g N/kg, 13.3 g P/kg and 51g K/kg. Five rate of chicken manure were used: (0, 1, 2, 3 and 4 ton/ha) and four rate of inorganic fertilizer were used(0, 23, 46 and 92 kg N/ha) were combined in a factorial design. The results showed that 4.6ton/ha of sole chicken manure to get the similar yield as to application of 92kgN/ha inorganic fertilizers. Combinations of 1.01 ton manure and 46 kg inorganic N or 2.0 ton/ha of chicken manure and 23 kg/ha inorganic N produced maize equivalent to 92 kg inorganic N fertilizer use alone. The chicken manure significantly improved the bulk density ($P<0.001$) and hydraulic conductivity ($P=0.034$) and the general trend increase in the chemical properties was observed. It was concluded that dependency on inorganic fertilizer could be reduced by combining chicken manure with small dose of inorganic fertilizer.

Citation: Makumba WI and Munthali MW (undated), Synergistic effect of composted chicken manure and small dose of inorganic fertilizer in maize production system Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

4.9 Effects of pigeon pea intercropping, inorganic fertilizer management and drought- and low-nitrogen tolerant varieties on maize productivity in Malawi

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A study was initiated at Makoka and Mbawa Research Stations in 2000/01 to 02 evaluate the role of pigeon pea intercropping, inorganic fertilizer timing and drought- and low-nitrogen tolerant open pollinated varieties (OPVs) on maize productivity. The first season was used to establish the maize pigeon pea intercropping systems along with a continuous maize control plot all under no fertilizer. Initial yields of unfertilized maize averaged 1.2 t/ha at Makoka and 0.69 t/ha at Mbawa. Pigeon pea litter fall was estimated at 1.5 t/ha at Makoka and 0.72 t/ha at Mbawa. Pigeon peas yields were 0.23t/ha at Makoka and 0.21 t/ha at Mbawa. In the subsequent season ('01/02), the following fertility management systems (FS), as main plots, were evaluated:-FS1-maize after maize without fertilizer; FS2:-maize after maize + pigeon pea intercropping, added inorganic fertilizer; FS3:-maize after maize +pigeonpea intercropping + a basal dressing of 23:21:0 +4S (NPKS); FS4:-maize after maize + pigeonpea intercropping + a top dressing of 23 kg/ha of N . Subplots had 4 varieties:-2 droughts –and low nitrogen tolerant OPVs (ZM621 and ZM521), compared against two checks (Masika, an OPV and SC627, a hybrid). Results showed that ZM621 and ZM521 at both sites maize yield yield components and height were the same for FS1 and FS2. FS3 and FS4 gave significantly higher yields over FS1 and FS2. At Makoka FS3 yielded 3.5t/ha, compared to about 1.0t/ha for FS1 and FS2 while FS4 gave a yield of 2.29t/ha. At Mbawa, FS3 yield was 1.89t/ha, compared to 2.79t/ha for FS4. There was no significant variety or FS x variety differences in yield and maize growth at all sites. Results in the third season were similar. It is concluded that maize-pigeon pea intercropping systems need to be complimented with inorganic fertilizer, and that the best time to add the fertilizer depends on inherit productivity of sites.

Citation: Kabambe VH, Mkandawire R, Ngwira AR and Kauwa AE (2008). Effects of pigeon pea intercropping, inorganic fertilizer management and drought- and low-nitrogen tolerant varieties on maize productivity in Malawi. Bunda Journal of Agriculture, Environmental Science and Technology 3: 13-19

4.10 Combined inputs of crop residues and fertilizer for smallholder maize production in southern Malawi

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Chronic shortage of food exists in the southern Malawi because of low maize (*Zea mays* L) yields due, in large part to soil fertility depletion. An approach to ameliorating soil fertility is strategic use of crop residues and mineral fertilizer. An on-farm experiment was conducted in two contrasting locations, Kasonga (9 farms) and Songani

(8 farms) that examined the effect and interaction of applying fertilizer and crop residues to soils. Crop residues consisted of maize stover and soybean (*Glycine max* (L) Merr.) trash of four cvs. Bossier, Ocepara 4, kaleya and Magoye that were obtained from the previous crop at each field. Average N organic inputs ranged between 15 kg N /ha for maize stover and 74 kg N /ha for soybeans and fertilizer N inputs were 0, 20, 40 and 60 kg N /ha with small accompanying P (0-13 kg P/ha). ANOVA of maize grain yield revealed significant effects of location ($P<0.001$), fertilizer addition ($P<0.001$) and crop residue type ($P=0.002$). Overall grain yield were much larger at Songani (2374 kg/ha) than Kasonga (812 kg /ha). Fertilization resulted in maize yields ranging between 901 kg/ha with no fertilizer to 1955 kg/ha with addition of 60 kg N and 13kg P /ha. ANOVA of total N uptake by maize revealed highly significant effects of location and fertilization ($P<0.001$) and significant effect of residue type ($P=0.002$). Overall N uptake by maize was 19.6 kg /ha at Kasonga and 62.7 kg/ha at Songani. The highest N uptake resulted from maximum fertilization and with residues of soybean cvs. Bossier and Magoye. Use of fertilizers and soybeans residues proved an effective strategy to increase maize yield but rather studies that examine the economics of these interventions is necessary.

Citation: Mwato IL, Mkandawire ABC and Mughogho SK (1999). Combined inputs of crop residues and fertilizer for smallholder maize production in southern Malawi. *African Crop Science Journal* 7 (4): 365-373

4.11 Evaluation of TwinN as a source of nitrogen for maize production

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Evaluation of TwinN as a source of N for maize production was conducted as a pot experiment in green house at Chitedze Agricultural Research Station. There were 2 soil types and 11 N treatments from TwinN and chemical fertilizers either in different combination or alone. The experiment design was RCBD. Soil and leaf samples were analysed for pH, OM, N, P, K and TwinN microbes. The results indicated that TwinN microbes were identified as beneficial bacteria and were present in the inoculated soil and maize plants at the end of 6 weeks after harvesting. There were significant differences ($P<0.001$) on maize biomass yield between soil type and among the treatments. The maize biomass yield was higher in the normal soil (pH6.3) (383,190 kg/ha) than the control (pH4.5) (121 265 kg/ha). Among the treatments, more mean biomass was yielded in all treatments from 2 to 11 (158, 518 to 375 405 kg/ha) than the control (151 110 kg/plot). The application of TwinN in combination with only half 23:21:0+4S gave biomass yield (284 146 kg/ha) which was much higher than those treatments applied with full fertilizer rates. The results suggested that the performance of TwinN was dependent on soil reaction. Soil OM mineralization and P and K uptake in maize plant from both soil samples was enhanced by TwinN, It was concluded that TwinN was a good source of N for maize biomass production.

Citation: Munthali W.M and E.D Mazuma (undated), Technical report, Chitedze Agricultural Research Station, Lilongwe, Malawi

4.12 The potential of green manure to increase soil fertility and maize yields in Malawi

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The effect of sole maize and green manures (*Mucuna pruriens*, *Crotalaria* and *Lablab purpureus*) on maize for two successive cropping seasons was determined in on-farm experiments at five locations in Malawi from 1996 to 1999. Legume residues were incorporated at two different times: early at peak biomass and late when the plant started to senesce. After growing and incorporation the green manure at the end of the 1996/97 growing season, maize was planted in 1997/98 and 1998/99 to test the effect of legumes on maize yields compared with continuous maize. Biomass production from early incorporated legume residues was 6.7 t/ha for *Mucuna*, 4.9 t/ha for *Crotalaria* and 4.9 t/ha for *L. Purpureus*, and for the incorporated legume residues it was 5.9, 5.2 and 4.1 t/ha for the same legumes, respectively. Of the three legumes, *L. purpureus* produced less biomass (average 4.2 t/ha) than the other two green manures and *Mucuna* produced the highest seed yield. Over the two seasons and across the five sites the application of inorganic fertilizer (35 or 69 kg N/ha) to maize significantly increased maize yields at all sites. Maize yields following green manure without inorganic fertilizer additions were much higher than yields from continuous maize with no fertilizer additions. Addition of inorganic fertilizer to legume resulted into increased maize yields at all sites, but the highest fertilizer use efficiency was obtained from the addition of 35 kg N /ha). There was no significant maize yield difference when followed early or late incorporated green manure across season and sites for three legumes. Results indicate that all the three green manures have potential to increase maize yields when used as sole green manure or in combination with inorganic fertilizers compared with sole maize alone.

Citation: Sakala WD, Kumwenda JDT and Saka AR (2003). The potential of green manure to increase soil fertility and maize yields in Malawi. *Biological Agriculture and Horticulture* 21: 121-130

4.13 Undersowing green manures for soil fertility enhancement in the maize-based cropping systems of Malawi

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Malawi's burgeoning human population has led to declining per capita food production and declining soil fertility in the continuously cropped maize systems. The use of inorganic fertilizers has fallen as the N: grain price ratio has risen. The challenge for agronomists in Malawi is to design, evaluate and disseminate cropping systems that will increase soil fertility and maize yields in regions where maize is planted every season. While green manures systems can accumulate >200kg N/ha when sole cropped, the magnitude of biomass produced and N₂ fixed by green manures when under-sown to maize is not known. An on-farm experimental program was established in the 1996/97 season at 11 sites in the central and southern Malawi to determine if intercropped green manures can produce the minimum biomass (>2000 kg/ha) necessary to improve soil fertility without reducing maize yields. Three factors (species selection, time of undersowing, and seeding rate) were examined in a 3 x 2 x 2 factorial experiment in a randomized completely block design. There were two replicates at each site. The factors were: Crop undersowing (Crotalaria juncea -CJ), Mucuna pruriens - MP), Lablab purpureus - LP) or Tephrosia vogelii - TV); Time of undersowing (First weeding -T1, Second weeding - T2); Seeding rate (Low - S1), Medium - S2). Crotalaria and Mucuna were grown at every site, while Lablab and Tephrosia were alternated at the third green manure species at a site. Lablab was grown at lowland while Tephrosia was planted at highland sites. Preliminary results after one season of growth showed that Tephrosia, Crotalaria and Mucuna, when undersown early, can produce significant amount of biomass (>2000 kg/ha) when intercropped with maize at low-fertility sites in Malawi. Tephrosia undersown at T1 yielded the most biomass, peaking at 6646 kg/ha at Bvumbwe. Tephrosia biomass produced was strongly correlated to rainfall received at a site. Mucuna, with aggressive climbing growth habit, was very competitive with maize when sown at first weeding. The MP T1 S2 treatment reduced maize yield by 60 % compared to sole maize controls. Lablab failed to yield more than 1000 kg/ha at any of the sites tested. Broadcasting small-seeded Crotalaria and Tephrosia led to low survival rates (<40%) for these species. The increased seed costs of broadcasting must be weighed against the labour advantages of this planting method. In the 1997/98 season, the experimental plots will be split and fertilizer to half the plots to determine whether the small organic and inorganic amendments can significantly increase maize yield. Future research will compare promising undersown green manure treatments (e.g. TV T1 S1, TV T1 S2 or CJ T1 S2) to other leguminous interventions (e.g. maize/ pigeonpea intercrops or soybean rotations) on the basis of N added to the soil systems and the economic net benefit. In this way Malawian farmers can choose the organic matter technology that best suites their needs.

Citation: R.A Gilbert, (2001). Undersowing green manures for soil fertility enhancement in the maize-based cropping systems of Malawi. In: Kumwenda J.D.T, Ngwira P, Kabambe V.H and M.K.M Komwa, editors. Maize Commodity Team Annual Report for the 1998/99 growing season, Department of Agricultural Research Services, Lilongwe, Malawi



Part 5: Liming and Application of Phosphate Rock

5.1 Soil fertility studies with compost and igneous phosphate rock amendments in Malawi

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Oxide mineralogy of acid tropical soil contributes to the problem of phosphorus (P) deficiency due to P sorption. The objectives of this research were to evaluate composting methods for improving the availability of phosphorus in igneous low grade (low reactivity). Tundulu phosphate rock and to test their effect on maize (*Zea mays* L) yield. Treatments included two composting materials (cattle manure and maize stover) which were applied at 3 ton/ha. Phosphate rock, composted at three levels: 50, 75 and 100 kg P₂O₅/ha. Epigeic earthworms were into the phosphorus were also applied as direct application of phosphate rock. Single superphosphate (SSP) was used as a standard treatment at a rate of 20 kg P₂O₅ /ha. There were 16 treatments in total. The experiment was arranged in a Randomized Complete Block Design with 3 replications. Soil analysis for P has shown no significant differences among treatments in improving the status of P in the soil at both Lunyangwa and Bembeke experimental sites both at seedling and harvest stages of maize, and among sampling times during the first season (1997/98). All P values were below the critical value for P in the soil and therefore maize yield realized was far below the potential for all treatments.

Citation: Nyirongo JCVB, Mughogho SK and Kumwenda JDT (1999). Soil fertility studies with compost and igneous phosphate rock amendments in Malawi, *African Crop Science Journal* 7(4), pp. 415-422

5.2 Effects of intercropping systems and the application of Tundulu Rock phosphate on groundnut grain yield in Central Malawi

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Low soil fertility remains a major constraint in agricultural production in Malawi. Legumes hold the promise of being a cheap alternative to improve soil fertility owing to their ability of fixing atmospheric nitrogen (N₂). Growing two leguminous crops on a piece of land at the same time and applying phosphorus (P) may increase N₂ fixation while at the same time realizing high grain yield from the legumes. A study therefore, was conducted to investigate the effect on nitrogen fixation and grain yield in a groundnut/pigeon pea intercrop, groundnut/maize intercrop treated with an indigenous rock phosphate (TRP) and groundnut treated TRP. Researcher designed but farmer managed trials involving eight farmers were mounted on farm. Treatments were laid out in a randomized complete block design. The results indicated an apparent significant ($P < 0.05$) groundnut grain yield reduction in the groundnut/pigeon pea intercrop (1,163 kg ha⁻¹) and groundnut/maize intercrop (910 kg ha⁻¹) below the groundnut sole crop (1,644 kg ha⁻¹) and the groundnut that was treated with the TRP (1,518 kg ha⁻¹). However, both intercrops showed yield advantage (LER >1.0) compared with the monoculture on equal land area. The application of the TRP appeared not to have affected the grain yield.

Citation: Phiri AT, Njoloma J, Kanyama-Phiri GY, Snapp SS and Lowole MW (2012) Effects of intercropping systems and the application of Tundulu Rock phosphate on groundnut grain yield in Central Malawi. *International Journal of Plant and Animal Sciences* 1 (1):011-020

5.3 Pyrite enhancement of Phosphorus availability from African phosphate rock: a laboratory study.

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Phosphate rock and pyrite deposits, indigenous to many African countries, may be useful to resource –poor farmers for increasing the P and S fertility of highly weathered tropical soils. A combination of PR and pyrite was examined as a means to increase the availability of P from five PR of African origins. Pyrite and PR were combined in several ratios (P/S) and incubated. Mixtures were periodically leached on a vacuum extractor with 0.01 M KCl for 6-mo period. Soluble P and pH of the leachate were measured. The pH of the leachates decreased with increasing levels of pyrite. In all cases, soluble P measured in the leachate was greatest from Togo to Uganda PR mixtures, much less from Zimbabwe PR and virtually nil in all but the highest pyrite treatments from both Tanzania

and Malawi PR mixtures. Citrate-soluble P was a less reliable predictor of P release than P and the percentage of CO₂, Al, and Fe in the PR and associated minerals. High pyrite levels with low-quality rocks generated P release comparable with that from untreated high quality rocks. The addition of Fe from pyrite apparently did not lead to precipitation of substantially amount of P as it was released from PR. The rocks responded very differently to the pyrite treatment. Although the method is promising for some rocks (Togo and Uganda), it is obviously not useful for other rocks (Malawi).

Citation: Lowell K and Weil RR (1995). Pyrite enhancement of Phosphorus availability from African phosphate rock: a laboratory study, *Soil Science Society Am. J.* 59:1645-1654

5.4 Efficacy of soil amendment with agricultural lime in reducing aflatoxin contamination in groundnuts in Malawi and Zambia

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Mycotoxins (of which aflatoxin is an example) are a group of secondary metabolites produced by fungi that are natural contaminants of agricultural products such as groundnuts. Aflatoxin contamination is one of the biggest challenges in groundnut production in Malawi and Zambia. Adequate plant nutrition to avoid plant nutrient stress is one of the ways to reduce aflatoxin contamination. An experiment was therefore conducted to determine efficacy of soil amendment with agricultural lime in reducing aflatoxin contamination in groundnuts. There were significant differences ($p=0.005$) among the lime levels at Chitedze. At Mbawa there were no significant differences ($p=0.051$) due to moisture stress that the site experienced. No significant differences ($p=0.557$) were also observed at Chitala due to high initial soil calcium.

Citation: Botoman L, Mazuma E, Kasankha L and Kaunda R (2015). Efficacy of soil amendment with agricultural lime in reducing aflatoxin contamination in groundnuts in Malawi and Zambia, *Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16)*, Department of Agricultural Research Services, Lilongwe, Malawi

5.5 Liming recommendation for crop production in Malawi

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Most upland soils in Malawi are highly weathered, low in pH and deficient in most of the soil nutrients. Over 40% of Malawi soils have a pH of less than 5.5 (in water) and it is recommended that liming should be applied when the soil pH is less than 5.5. Malawi has large deposits of limestone (dolomite and calcite) and the use of dolomite to amend for soil acidity will in addition supply calcium and magnesium to the crop. Due to the need to increase maize yields in acid soils, liming studies were conducted in the country and the liming technology was released for use by farmers in the country particularly smallholder farmers. In order to disseminate the Liming Technology with support from Consortium of Soil Fertility for Southern Africa conducted liming demonstrations in the for two seasons in Dedza and Ntcheu. Farmers have seen good response due to liming. Locally mined dolomitic lime along Zalewa road was used. Liming studies were finalized and recommended that farmers apply 200kg/ha by splitting the newly made ridge and broadcasting the lime along the ridge and incorporating while covering the ridge. Fertilizer is applied as is recommended in the country. Liming significantly increased grain yield and application of lime at 2000kg/ha was recommended and the gross margin was high at this rate as well. The liming demonstrations showed that liming increased maize yields compared to farmers practice (no lime applied). It is now recommended that liming should be encouraged in the county and the coming of Zalewa Agricultural Lime Company should support the Department of Agricultural Research Services to conduct demonstration throughout the country and allow the quality of their lime assessed continuously. Once the farmers have seen the benefits of liming and that lime is made available the farmers will ultimately adopt the technology.

Citation: A.D.C Chilimba (undated), *Liming recommendation for crop production in Malawi*, Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

5.6 Potential use of Thundulu rock phosphate (RP) on maize; frequency of application of RP and Diammonium phosphate (DAP) on maize (1995/1996 season)

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A study was initiated in the 1993 crop season in three sites (Mbawa, Meru and Zombwe) and in the 1994/95 crop season at Bembeke to determine the initial and residual agronomic effectiveness of the Thundulu rock phosphate (RP) on maize yield. At Mbawa and Meru the application of Diammonium phosphate (DAP) gave higher yields than Thundulu rock phosphate in all the three years of testing, and in only one year (1993/94) and three (1995/96) at Zombwe. Maize responded to P application from DAP only in 1993/94 and 1995/96 seasons at all sites, and from RP in second season (1994/95) season only at Zombwe and in third season only at Mbawa, Zombwe and Meru. The largest response was from the application of 30 kg P₂O₅ /ha. In 1994/95 season, the low and poorly distributed rainfall pattern resulted in no response to P source or application rates. At Bembeke (acidic soils) maize responded to Thundulu in the first year of application (29% yield increase over plots with no P application). The residual effects of P were more than lower at rate of application. These results show that all sites tested Thundulu rock phosphate was somewhat effective in supplying only third season. This suggests that further research is required to investigate the means of improving the effectiveness of Thundulu rock phosphate in the first year of application.

Citation: Kumwenda JDT, Ganunga .P. and Saka AR (1996), Potential use of Thundulu rock phosphate (RP) on maize; frequency of application of RP and Diammonium phosphate (DAP) on maize (1995/1996 season), Technical Report, Chitedze Agricultural Research Station, Lilongwe

5.7 The potential of Thundulu rock phosphate for maize production in Malawi

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The two most common limiting nutrients for maize production in Malawi are Nitrogen and Phosphorus. Deposits of phosphate rock (RP), in excess of million metric tons, have been identified near Thundulu near Lake Chilwa. Agronomic trials were started in the 1990/01 season to determine the potential of Thundulu RP for increasing maize yields on phosphorus deficient soils results from the 1991/02 season show that the recommended fertilizer application method of dolloping is not effective for RP in the season of application. Band application of RP gave significant yields increases that were comparable with those that were obtained from application of Triple phosphate (TSP) in the same season. Two acidifying fertilizers, urea and sulphate of ammonia, were compared with calcium ammonia nitrate to determine the whether the reactivity of RP could be increased by acid producing nitrogen fertilizer. No significant differences were found. The research shows that indigenous RP may have potential for replacing the imported phosphorus fertilizers.

Citation: R.B Jones and J.W Wendt, (1995). The potential of Thundulu rock phosphate for maize production in Malawi, Paper presented at the XIV annual conference of the association for advancement of Science and Technology of Malawi.

Part 6: Legumes, Genotypes and Integrated Soil Fertility Management Technologies

6.1 Evaluation of the effect of leguminous best bet comparisons on maize yield, soil fertility and witchweed control

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A study was initiated at Mponela in Kasungu in 1997/98 and at Mpingu near Chitedze Agricultural Research Station in 1998/99 season to evaluate the role of selected legume rotations and intercropping systems on maize yield, soil fertility and witchweed (*Striga asiatica* L. kuntze) suppression. Average yields for fertilized and unfertilized maize were 660 and 187 kg/ha. Intercropping with pigeon peas or Tephrosia undersowing 2 weeks after maize suppressed maize yield. Estimated dry matter yield of legumes stover was 1.04, 2.48 and 3.84 t/ha for groundnuts, Tephrosia and mucuna. Witchweed incidence was quite low. In 1998/99 maize yield were similarly low. Average witchweed emergence was 10.8 plants m⁻². There was apparent suppression of emergence in the tephrosia undersowing treatment. At Chitedze in 1998/99, which was the initial season, average maize yields from fertilized plots was 0.93 t/ha.

Citation: V.H Kabambe and R Gilbert, (2001). Evaluation of the effect of leguminous best bet comparisons on maize yield, soil fertility and witchweed control, Maize Commodity Team Annual Report for the 1998/99 growing season, Department of Agricultural Research Services, Lilongwe, Malawi

6.2 Adoption of fertilizer and hybrid seeds by smallholder maize farmers in southern Malawi

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Despite decades of agricultural policies that promoted the adoption of fertiliser and hybrid seed technologies as ways of improving productivity in maize farming, smallholder farmers in Malawi have been relatively slow to adopt the new technology. Using bivariate profit analysis and controlling for technology acquisition through grants, we found that fertiliser adoption was positively associated with higher levels of education, larger plot sizes and higher non-farm incomes, but negatively associated with households headed by women and distance from input markets. The adoption of hybrid seeds is positively associated with market-based land tenure systems and fertile soils, but negatively associated with age of the farmer and distance from input markets

Citation: Chirwa EW (2005). Adoption of fertilizer and hybrid seeds by smallholder maize farmers in southern Malawi, Development Southern Africa 22 (1): 1-12

6.3 Alternative soil fertility management options in Malawi: An economic analysis

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In this paper, we analyse the factors that influence the productivity of maize among smallholder farmers, given that unfavourable output and input market conditions throughout the 1990s have compelled smallholder farmers into unsustainable agricultural intensification. We use farm-household survey data in order to compare the productivity of smallholder maize production under integrated (ISFM) and chemical-based soil fertility management using a normalised trans-log yield response model. The results indicate higher maize yield responses for integrated soil fertility management options after controlling for the intensity of fertilizer application, labour intensity, seed rate, land husbandry practices, as well as selected policy factors. The estimated model is highly consistent with theoretical conditions. Thus, we conclude that the use of ISFM improves maize productivity, compared to the use of inorganic fertilizer only. Since most farmers in the maize-based farming systems are crowded out of the agricultural input market and can hardly afford optimal quantities of inorganic fertilizer, enhancement of ISFM is likely to increase their maize productivity. We finally highlight areas of policy support needed to enhance ISFM uptake in smallholder maize-based farming systems.

Citation: Sauer J, Tchale H and Wobst P (2006). Alternative soil fertility management options in Malawi: An economic analysis, Journal of Sustainable Agriculture 29 (3): 29-53.

6.4 Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi

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Sustainable intensification of smallholder farms in Africa is highly dependent on enhancing biological nitrogen fixation (BNF). Legume diversification of maize-based systems is a core example of sustainable intensification, with the food security of millions of farm families at stake. This study highlights the constraints and opportunities associated with the adoption of legumes by smallholder farmers in southern Africa. A two-part survey of households and farm fields (n=88) was conducted in the Ekwendeni watershed of northern Malawi. Participatory research and education activities have been underway for over a decade in this region, resulting in expanded uptake of a range of legume species as intercrops and in rotation with the staple maize crop. Farmer adoption has occurred to a varying extent for soybean (*Glycine max*), pigeon pea (*Cajanus cajan*), velvet bean (*Mucuna pruriens*) and fish bean (*Tephrosia vogelii*). Farmers, working with the project valued pigeon pea and other legumes for soil fertility purposes to a greater extent than farmers not working with the project. Legumes were valued for a wide range of purposes beyond soil cover and fertility enhancement, notably for infant nutrition (at least for soybean), insect control, and vegetable and grain production for both market and home consumption. Literature values for BNF in tropical legumes range up to 170kg N ha⁻¹ for grain and 300 kg N ha⁻¹ for green manure species; however, our field interviews illustrated the extent of constraints imposed by soil properties on smallholder fields in Malawi. The key edaphic constraints observed were very deficient to moderate phosphorus levels (range 4–142, average 33mg kg⁻¹), and moderately acid soils (range pH 5.1–7.9, average 6.2). The per farm hectareage devoted to legume production relative to maize production was also low (0.15 versus 0.35ha), a surprising find in an area with demonstrated interest in novel legume species. Further, farmers showed a strong preference for legumes that produced edible grain, regardless of the associated nutrient removal in the harvested grain, and did not sow large areas to legume crops. These farm-level decisions act as constraints to BNF inputs in maize-based smallholder cropping systems. Overall, we found that legume productivity could be enhanced. We documented the value of policies and educational efforts that support farmers gaining access to high-quality seeds, amendments for phosphorus-deficient soils, and promotion of multipurpose legumes that build soils through leafy residues and roots, as well as providing grain for food security and sales.

Citation: Mhango WG, Snapp SS and Kanyama-Phiri GYK (2013). Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi, *Renewable Agriculture and Food Systems* 28 (3): 234-244.

6.6 Improving productivity of maize based systems through the use of legumes

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Low soil fertility is one of the challenges to increased productivity of maize based systems of smallholder farms. Legume species can help to address low soil N through the Biological Nitrogen Fixation (BNF) and residue incorporation. In this study the main objective was to evaluate the effect of diversified legume cropping systems on BNF and crop yields. Participatory on farm trials were conducted in northern Malawi in 2007/08 and 2008/09 cropping seasons. Treatments included groundnuts, pigeonpeas, and maize planted in sole or intercrop. These were rotated with maize. A baseline survey showed that soil fertility was highly variable and degraded with low organic matter (12±3.7 g kg⁻¹). Farmers valued a wide range of legume traits that included food, yield, maturity period, soil fertility and market potential. Results from on farm trials showed that interspecific competition, inorganic P and plant density were drivers of crop growth and BNF. Under low yielding environments, sole groundnuts and groundnuts intercropped with pigeonpea (GNPP) produced more calories and proteins than sole or maize intercropped with pigeonpea (MZPP). Legume cropping system increased subsequent maize yield by 27-72% over continuous maize, and 69-200% with integrated soil fertility management. Intercropped species were more efficient at utilizing resources than sole stands as indicated by land equivalent ratios (LERs)>1, 1.50 and 1.56 for GNPP and MZPP respectively. Farmers' preference was for technologies that provide multiple benefits. Constraints to legume adoption were socio-economic (seed availability, labor), biophysical (pests in pigeonpea, agronomic practices) and natural (unpredictable rainfall).

Citation: Mhango W, Snapp S.S and Kanyama-Phiri G.Y, (2014). In: Kabambe V, Tembo Y and Ngwira A, editor. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 139

6.7 The Effect of phosphorous and sulfur fertilisers on grain legume and maize productivity in northern Malawi

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Onfarm trials were carried out in Champhira and Ntchenachena Extension Planning Areas (EPAs) in northern Malawi in 1999/00 and 2000/01 crop seasons to determine the effect of phosphorous (P) and sulphur (S) on performance of grain legumes and their effect on the subsequent maize crop. The trials were researcher designed but farmer managed with five farmers in each EPA as single replicates. In 1999/00 crop season, groundnut (*Arachis hypogea*), bambara groundnut (*Vigna subterranean*), soybean (*Glycine max* L. Merrill) and maize (*Zea mays*) were grown with and without nitrogen, phosphorus and sulphur fertilisers. The fertilizer rates were 0 kg P and S ha⁻¹, 20 kg P and 4 kg S ha⁻¹, 40 kg P and 8 kg S ha⁻¹. In 2000/01 crop season, maize was grown on all plots as a test crop. Soil chemical analysis indicated that P and S application had no effect on total N and P, and organic carbon but the two sites were significantly different ($p=0.001$) with Ntchenachena having higher values except for available P, suggesting that soils in Ntchenachena fixed more P. Soybean and groundnut recycled more P in the stivers than maize and bambara groundnut. In 1999/00 crop season, a positive response to fertilizer application rates was observed in maize and soybean grain yield, but no effect on the grain yield of groundnut and bambara groundnut. Application of fertilizer increased stover production in all crops except bambara groundnut. In 2000/01 crop season, maize grain yield varied with the type of crop residues that were incorporated ($p=0.003$). Maize following legumes gave higher grain yield than maize-maize rotations. Legume crop residues from fertilized treatments increased maize grain yield at Champhira by 44%. There were correlations between the amount of crop residues incorporated (x) and maize grain yield (y) from groundnut ($y=0.27x + 474$, $R^2=0.60$) and soybean ($y=0.163x + 401.6$, $R^2=0.98$) in Champhira; and Ntchenachena ($y=-0.431x + 214$, $R^2=0.88$) for soybean residues.

Citation: Mhango W.G., Mughogho S.K., Sakala W.D. and Saka A.R. (2008). The effect of phosphorus and sulphur fertilizers on grain legume and maize productivity in northern Malawi. *Bunda Journal of Agriculture, Environmental Science and Technology* 3 (2): 20-27.

6.8 Assessment of resource requirement and output potential of soil management technologies in Zomba

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A study was conducted in Zomba, Southern Malawi in order to assess resource requirement and output potential of existing and introduced soil management technologies on smallholder food production. Sesbania (*Sesbania sesban*), Tephrosia (*Tephrosia vogelii*), and Pigeon peas (*Cajanus cajan*) were used as sources of green manure in improved plots whereas the control plots used maize stover and natural weeds as sources of nitrogen. The amount of time and labour involved in the management of each practice were monitored throughout the growing season. Results indicate that green manures are superior to maize and weeds commonly incorporated by smallholder farmers to improve yields. Management of green manure requires more labour and time than that of maize stover and weeds. Economic importance of the multipurpose tree species and maize in terms of nitrogen contribution to the soil and maize yields is also discussed.

Citation: B. C.G. Kamanga, G.Y.Kanyama-Phiri and S Minae, (1997). Assessment of resource requirement and output potential of soil management technologies in Zomba, Paper presented at soilfnet at Mutale, Zimbabwe, 7- 11 July, 1997

6.9 Best-bet soil fertility management options: The case of Malawi

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Agriculture is the backbone of food and economic security in Malawi, accounting for 90% of food produced and 10% of export earnings. However, soil fertility depletion under continuous cultivation, in the face of increased human population pressure, combines to constrain agricultural production. As a result the country is trapped in a vicious cycle of chronic food insecurity. Several decades of research in Malawi have demonstrated potential for various best-bet soil fertility management options for mitigating the soil fertility decline. The inorganic fertilizer option has proved to be the most reliable. However, this option is largely beyond the reach of the majority of smallholder farmers in Malawi.

Incorporation of crop residues and weeds has proven to be the most ineffective owing to their wide carbon to nitrogen ratios and low nutrient content. Organic carbon and nitrogen from compost and livestock manures have been demonstrated to be richer in nutrients than residues and weeds except that their wide application is constrained by labour bottlenecks. Integrated nutrient management involving nitrogen fixing herbaceous legumes such as groundnuts, mucuna, clotalaria and Lab lab or tree legumes such as Sesbania, Pigeon peas, Tephrosia, Gliricidia and Tithonia, with and without compost and livestock manures have proved to be the best-bet options under Malawi conditions. This paper discusses the merits and demerits of integrated soil fertility management options drawing experiences from over a decade of agroforestry research under various landscape positions within watersheds in Malawi.

Citation: G.Y. Kanyama-Phiri, (2005). Best-bet soil fertility management options: The case of Malawi, African Crop Science Conference Proceedings, Vol. 7. pp. 1039-1048

6.10 On-farm assessment of legume fallows and other soil fertility management options used by smallholder farmers in southern Malawi

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This study evaluated the performance of tree legumes and other soil fertility management innovations used by farmers. The objectives of the study were to: examine the extent that farm attributes, typology of farmers and field management practices have affected the adaptation and use of agroforestry technologies for soil fertility management and compare the agronomic performance and farmer assessment of agroforestry and other soil fertility management options, across a wide range of farmer types and field conditions, with a view to establishing the contribution of management variables to variations in yield estimation. Maize yield and farmer rating were assessed in Type II (researcher-designed, farmer-managed), Type III (farmer-designed and managed) trials and extension farmers. Results from 152 farmers show that agroforestry increased the yield of maize by 54-76% compared to unfertilized sole maize used as the control. When amended with fertilizer, the yield increase over the control was 73-76% across tree species. This indicates that farmers who had combined agroforestry with inorganic fertilizer experienced increase in maize yield attributable to the synergy between organic and inorganic fertilizer. In gliricidia-maize intercropping, higher maize yield was obtained by farmers who pruned twice. Combination of two prunings and fertilizer use gave the highest yield increase (148%) over the control and the third pruning was superfluous when fertilizer was applied. Without fertilizer, maize yield in agroforestry plots intercropped with pigeon pea was higher than those plots without pigeon pea. Planting date, fertilizer application, use of agroforestry and maize variety explained about 44% of the variation in maize yield on farmers' fields.

Citation: Akinnifesi FK, Sileshi G, Franzel S, Ajayi CO, Harawa R, Makumba W, Chakeredza S, Mngomba S., de Wolf JJ. and Chianu N (2009). On-farm assessment of legume fallows and other soil fertility management options used by smallholder farmers in southern Malawi, Agricultural Journal 4 (6): 260-271.

6.12 Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi

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Maize (*Zea mays* L.) is a major staple food in Malawi. However, low soil fertility resulting from low and inappropriate use of fertilizer practices, continuous monocropping and inappropriate crop residues management coupled with limited resources and droughts keep yields low. This had led to a quest for sustainable solutions such as maize-legume intercropping or rotation including more efficient use of crop residues in smallholder farming systems. Innovation platforms (IP) built around learning centres (LC) located on smallholder farmers' fields in target locations were used as an approach to disseminate integrated soil fertility management (ISFM) technologies and build capacity of farmers, extension staff and other stakeholders. Rotating maize with either groundnut or groundnut intercropped with pigeonpea increased maize grain yield (3678 and 3071 kg ha⁻¹

respectively) compared to sole maize (2260 kg ha⁻¹). These preliminary findings were linked to farmer assessment of technologies where farmers participating in the LCs expressed strong interest in the maize legume rotation technologies. Associated farmer field days outlined constraints underlying technology choice, information that is not usually considered in conjunction with on-farm experimentation. Although, the legumes were highly productive, farmers expressed worries about legume seed availability, disease incidences, weeds infestations and livestock damage. Participating farmers commonly manage residues by burning. Promotion and experimentation with more efficient use of legume residues have shown short-term positive impacts in efforts to promote scaling-out of best fit legume technologies. This study reports the value of multi-stakeholder partnering in scaling-out and evaluation of best fit legume technologies and adoption constraints.

Citation: Ngwira A.R, Kabambe V.H , Kambauwa G, Mhango W.G, Mwale C.D, Chimphero L, Chimbizi A and Mapfumo P, (2012). Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi, *African Journal of Agricultural Research* Vol. 7(6), pp. 918-928

6.13 Soil fertility management choice in the maize-based smallholder farming system in Malawi

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The paper analyses the factors that affect smallholder farmers' choice of soil fertility management options in Malawi using the maximum likelihood estimation procedure. Results from the Double-Hurdle model indicate that relative input cost, wealth indicators, farmer education, market and credit access, food security index and land pressure are the main factors that largely influence farmers' choice and intensity of input investment. Although there is a high and positive correlation between probability of adoption and intensity of application, factors that influence adoption are not necessarily the same as those that influence the intensity of application, thereby confirming our hurdle hypothesis. Moreover, market access and input cost reinforce each other in determining the effective cost, which farmers perceive as the major factor that influences their soil fertility management decisions. The paper concludes with policy implications aimed at renewing the focus on soil fertility management in terms of technology development and transfer as well as public policy in support of agricultural market development.

Citation: H Tchale and P Wobst (undated), Technical Report, Soil fertility management choice in the maize-based smallholder farming system in Malawi, Department of Economics and Technical Change, University of Bonn, Germany

6.14 Sustainable soil management options for Malawi: can smallholder farmers grow more legumes?

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Sole-cropped, unfertilized maize is the dominant cropping system throughout southern Africa. Yields have become stagnant and legumes are frequently advocated as an affordable option for resource poor farmers, to enhance productivity. Farmer participatory research was employed to test legume intensification as a means to improve maize-based systems in Malawi. A range of options were evaluated, from grain/legume intercrops of long-duration pigeonpea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*) rotated with maize (*Zea mays*), to a relay green manure system of maize with fishbean (*Tephrosia vogelii*). Two years of on-farm experimentation indicated that under on-farm conditions legume-intensified systems produced residues that contained about 50 kg N/ha per year, two-fold higher than sole-cropped maize residues. Grain yields from legume-intensified systems were comparable to yields from continuous sole maize, even in a dry lakeshore ecology. These preliminary findings were linked to farmer assessment, where farmers participating in the trials expressed strong interest in the technologies. Yet the probability of adoption remains uncertain. Associated surveys outlined constraints and trade-offs underlying technology choice, information that is not usually considered in conjunction with on-farm trials. Although the legumes were highly productive, farmers expressed worries about the marginal loss of maize production. While the trial performance was similar across regions, differences in market condition, farm resources and household composition appears to stimulate different technology choices. Farmers weigh the benefits of weed suppression and potential cash earnings, against the costs of seed, problems of seed access, labor requirements and problems of grain market access and price. Surveyed farmers commonly manage residues by burning. Promotion and experimentation with more efficient use of legume residues may offer higher short-term impacts than efforts to promote adoption of another cash crop. Ultimately, adoption and soil fertility benefits may depend on market returns to legume production. This study documents the value of researchers and farmers partnering in evaluation of technologies, adoption constraints and competing technology choices.

Citation: Snapp SS, Rohrbach DD, Simtowe F and Freeman HA (2002). Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? *Agriculture, Ecosystems and Environment* 91, pp. 159–174

6.15 Towards integrated soil fertility management in Malawi: incorporating participatory approaches in agricultural research

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In order to effectively develop integrated soil fertility management strategies and disseminate the resulting technologies, we need new approaches that will enable farmers and researchers to build working partnerships. Participatory research is one option, but it is often considered too time-consuming and criticised for not generating quantitative data. Researchers in Malawi have taken up the challenge to overcome these constraints, and have developed both a short-term and a longer-term approach to participatory research. This paper describes the various steps followed in two case studies that followed each approach. The short-term approach tested and disseminated 'best bet' technologies in target villages in four different agro-ecological zones. Over three years researchers developed a 'mother & baby' satellite trial that was designed to meet both their own and farmers' requirements. They used innovative trial designs and consultative methods, and in many sites obtained promising results from on-farm trials with intensified cropping systems incorporating legumes. Biological performance was measured against the farmers' assessments of the new technologies, and farmers also stressed the importance of testing a range of options, such as a wide range of legumes grown with small amounts of mineral fertiliser. The longer-term programme was implemented over a period of more than five years. This involved a participatory, community-oriented approach to work in a watershed located in a densely populated area of southern Malawi. The research addressed the problem of eroded slopes used by farmers with limited access to resources. It was difficult to make progress on these degraded sites: maize generally performed very poorly on the steep slopes, and without nitrogen fertiliser the legume-based technologies were not very productive. In flatter areas and valleys the *Sesbania sesban* inter-crop system produced the highest yields, but the drawback of this system was that it required the highest investment in terms of labour. We believe that it is important for researchers and farm advisors to have a long-term commitment to working with farm communities, particularly for problematic areas such as the eroded, degraded sites and small land holdings typified by the Songani watershed in Southern Malawi. Our findings indicate that there is considerable scope for using participatory research methods to develop more appropriate technologies. These two case studies show how farmers' input can be incorporated regularly into the early stages of research. Policy makers may need to be drawn into this work as well, as there appear to be no easy answers to the problems posed by degraded sites. Dissemination of 'best bet' technologies for other, better-endowed sites may also benefit from policy interventions.

Citation: Kanyama-Phiri G.Y, Snapp S.S, Kamanga B.C.G and Wellard K, (2000). Towards integrated soil fertility management in Malawi: incorporating participatory approaches in agricultural research, *Managing African Soils* No. 11, pp. 1-27

6.16 Yields and qualities of pigeonpea varieties grown under smallholder farmers' conditions in Eastern and Southern Africa

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Pigeonpea is one of the few crops with a high potential for resource-poor farmers due to its complementary resource use when intercropped with maize. A three year comprehensive comparative study on the performance of six pigeonpea (*Cajanus cajan*) varieties on farmers' fields in Eastern and Southern Africa where intercropping with maize is normal practice, was undertaken. The varieties were tested for accumulation of dry matter (DM), nitrogen (N) and phosphorus (P) in all above-ground organs for three years under farmers' conditions. The study revealed that the latest introduced ICEAP 00040 outperformed all the other tested varieties (ICP 9145; ICEAP 00020, ICEAP 00053, ICEAP 00068, and a local variety called "Babati White") under farmer-managed conditions. The harvest indices (HI), ranging from 0.08 - 0.15 on dry matter (DM) basis, were relatively low and unaffected ($P > 0.05$) by the environmental variation. The N harvest index (NHI) was 0.28 and P harvest index (PHI) was 0.19.

The better responses of ICEAP 00040 to favourable conditions could however only be realised in a minority of cases as yields generally were low. These low yields are still a major challenge in African smallholder agriculture as pulses play an important role in soil fertility maintenance as well as in the household diets.

Citation: Høgh-Jensen H, Myaka FA, Sakala WD, Kamalongo D, Ngwira A, Vesterager JM, Odgaard R and Adu-Gyamfi JJ (2007). Yields and qualities of pigeonpea varieties grown under smallholder farmers' conditions in Eastern and Southern Africa, *African Journal of Agricultural Research* 2 (6): 269-278

6.17 Biological nitrogen fixation in sole and doubled-up legume cropping systems on the sandy soils of Kasungu, Central Malawi

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Nitrogen is the most limiting element in Malawi soils with respect to crop production. However, grain legumes that are associated with biological nitrogen fixation are commonly grown in the country. Results are reported of a study on evaluation of the effects of sole cropped and doubled-up legume systems (legume-legume intercrop) on biological nitrogen fixation on the Ultisols of Kasungu district, Central Malawi. The modified nitrogen difference method was used to estimate the amount of nitrogen fixed per hectare. The total amount of nitrogen biologically fixed in each cropping system (that is, for intercrops, this means adding together amount of nitrogen fixed by the component crops) showed significantly ($p < 0.05$) higher mean nitrogen amount in the pigeon pea/groundnuts doubled-up cropping system (82.8 kg N ha⁻¹) that was 33 and 35% more nitrogen than those of the sole groundnuts (55.8 kg N ha⁻¹) and sole pigeon pea (54.1 kg N ha⁻¹), respectively. However, the pigeon pea/soybean doubled-up (53.6 kg N ha⁻¹) was only significantly higher than that for the sole soybean (35.8 kg N ha⁻¹) but resulted in nitrogen amount similar to that for the sole pigeon pea which implies a large suppression on intercropped pigeon pea biological nitrogen fixation. This could be attributed to competition for light and nutrients presented to the pigeon pea in the pigeon pea/soybean intercrop in early stages of development by the fast growing bushy solitaire soybean.

Citation: Njira K. O. W, Nalivata PC, Kanyama-Phiri GY and Lowole MW (2012). Biological nitrogen fixation in sole and doubled-up legume cropping systems on the sandy soils of Kasungu, Central Malawi, *Journal of Soil Science and Environmental Management* 3(9), pp. 224-230

6.18 Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi

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Loss of soil fertility is one of the major challenges to agricultural production in Malawi, with nitrogen considered the main limiting factor to crop growth. An on-farm study was conducted on an Ultisol in Kasungu district, Central Malawi, to evaluate the effects of sole cropped and doubled-up grain legumes' (legume-legume intercrop) residues and inorganic N supplement on maize yields. Maize was planted in a randomized complete block design experiment where plots were split into different top dressing N fertilizer levels. Results showed that combinations of residues of sole cropped groundnuts with 23 kg N ha⁻¹ and 46 kg N ha⁻¹ inorganic fertilizer top dressings; residues of inoculated sole cropped soybean, sole cropped pigeon pea, and pigeon pea/groundnut intercrop with 46 kg N ha⁻¹ inorganic fertilizer top dressing resulted in maize grain yields of 1942 kg ha⁻¹ and 2152 kg ha⁻¹; 2056 kg ha⁻¹, 1838 kg ha⁻¹, and 1806 kg ha⁻¹ respectively, that were significantly ($p < 0.05$) higher than those from treatments of maize residues with the same rates of inorganic N fertilizer top dressing (maize grain yields of 1174 kg ha⁻¹ and 1569 kg ha⁻¹ respectively). It was also observed that both sole cropped and doubled-up legume residues with 23 kg N ha⁻¹ and 46 kg N ha⁻¹ inorganic fertilizer produced maize grain yields that were comparable to that produced from a treatment of maize residues supplemented with 92 kg N ha⁻¹. From this study it can be concluded that incorporation of both sole cropped and doubled-up legume residues with a supplement of 23 kg N ha⁻¹ inorganic fertilizer as top dressing in maize production can be a good option for resource poor farmers in Central Malawi and similar agro-ecological zones

Citation: Njira KOW, Nalivata PC, Kanyama-Phiri GY and Lowole MW (2013). Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi, *Agricultural Science Research Journals* 3(3): 97-106

6.19 Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility

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Legume species are uniquely suited to enhance soil productivity and provide nutrient-enriched grains and vegetables for limited-resource farmers. Yet substantial barriers to diversification with legumes exist, such as moderate yield potential and establishment costs, indicating the need for long-term engagement and farmer-centered research and extension. This review and in-depth analysis of a Malawian case study illustrates that farmer experimentation and adoption of legumes can be fostered among even the most resource-poor smallholders. Multi-educational activities and participatory research involving farmer research teams was carried out with 80 communities. Over five years more than 3000 farmers tested legumes and gained knowledge of legume contributions to child nutrition and soil productivity. The average area of expansion of legume systems was 862m² in 2005; 772m² for women and 956m² for men indicating a gender dimension to legume adoption. Farmers chose edible legume intercrops such as pigeonpea and groundnut over the mucuna green manure system, particularly women farmers. Interestingly, expansion in area of doubled-up edible legumes (854m² in 2005) was practiced by more farmers, but was a smaller area than that of mucuna green manure system (1429m²). An information gap was discovered around the biological consequences of legume residue management. Education on the soil benefits of improved residue management and participatory methods of knowledge sharing were associated with enhanced labour investment; 72% of farmers reported burying legume residues in 2005 compared to 15% in 2000. Households reported feeding significantly more edible legumes to their children compared with control households. The participatory research that incorporated nutritional education fostered discussions within households and communities, the foundation for sustained adoption of legume-diversified systems

Citation: Kerr RB, Snapp SS, Chirwa M, Shumba L and Msachi RS (2007). Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility, *Expl Agric.* 43, pp. 437–453

6.20 Integrated management for Striga control in Malawi

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In Malawi, *Striga asiatica* (L.) Kuntze infestation presents a serious constraint to small-scale farmers who must grow cereals, in particular, maize, for food. The successful introduction of highly productive and acceptable flint maize hybrid is under threat from *Striga*. Little is known of the economic importance of *Striga* in other host crops. When the control of this weed is reviewed, it appears that the information applied of the management of *Striga asiatica* is largely based on extensive work on *Striga* is an integrated approach that included a combination of methods that are within reach of the farmer and considered worthwhile by the farmer. The paper attempts to mould a topical inventory of work on *S. asiatica* in the region into a research perspective for the small scale farmer in maize based cropping systems in Malawi.

Citation: Mloza-Banda HR and Kabambe VH (1996). Integrated management for *Striga* control in Malawi, *African Crop Science Journal* 4 (2), pp.263-273

6.21 Evaluation of common beans lines for tolerance to high soil acidity (Aluminum toxicity)

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Excessive soil acidity is a continuous problem in many soil agricultural areas in Malawi and increasingly becoming a limiting factor in common beans (*Phaseolus vulgaris*). Aluminum is the major cation associated with soil acidity which is one of the precursors to low soil fertility which leads to productivity. However, breeding efforts have shown that genetic differences in soil acidity can be improved. A field study was carried out during the 1998/99 season at Bembeke to evaluate some 208 lines for tolerance to high soil acidity. The soil classified as Oxic Haplustalf. It is sandy clay loam in texture and strongly acidic in reaction (4.5-5.0, Al salt 40-60%). The organic matter and nitrogen contents are medium (1.52-4.5% and 0.12-0.20% respectively). Phosphorus is low (25-33 ppm); whereas potassium, calcium and magnesium are medium, low and high (0.11-0.40, 2.5-5.0 and 0.6-3.0) Cmol/kg soil, respectively). Fifty five lines have excelled in the preliminary field evaluation.

Citation: Chigowo M.T, Chirwa R. M, Kisyombe C.T, Nyirenda N.E and Mviha P.J.Z (1999). Evaluation of common beans lines for tolerance to high soil acidity (Aluminum toxicity), Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

6.22 Analysis of defense genes in response to soil borne pathogen white mold infection in different common bean (*P. vulgaris*) cultivars

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White mold, caused by *Sclerotinia sclerotiorum* (Lib) De Bary, is a serious yield reducing fungal pathogen of common beans (*Phaseolus vulgaris*). It is a soil borne pathogen that persists in the soil for up to five years. Due to increase in bean production and variable weather patterns the incidence of severity of white mold is also increasing in the tropical countries like Malawi. Understanding the function of quantitative genes resistance and their mode of expression is necessary to enable breeders to select which genomic to deploy in marker assisted selection. We investigated the role of three genes; PGIP, Glucanase, and PAL in the defense response of different bean genotypes (AN-37, P02630, beryl and G122) following infection with *Sclerotinia sclerotiorum*. Analysis of defense genes in response to infection of white mold showed variable temporal transcription. These results suggest that the resistance reported in different cultivars of beans to white mold is due to different defense pathways. The induction of defense genes at wounding may have the confounding role in the interpretation of results from the greenhouse straw test which usually does not correlate with the field tests. There is a need to investigate the role of other genes to gain a better understanding of the variation in reaction of white mold in different cultivars of common beans.

Citation: Mkwaila W and Kelly J D, (2014). Analysis of defense genes in response to soil borne pathogen white mold infection in different common bean (*P. vulgaris*) cultivars, In: Kabambe V, Tembo Y and Ngwira A. Proceedings of the first Integrated Soil Fertility Management Symposium, Held at Sunbird Lilongwe Hotel, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 41-49

6.23 Assessment of resource requirement and output potential of soil management technologies in Zomba, Malawi

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A study was conducted in Zomba, southern Malawi to assess the resource requirement and output potential of existing and introduced soil management technologies on smallholder food production. *Sesbania* (*Sesbania sesban*), *Tephrosia* (*Tephrosia vogelii*) and pigeon peas (*Cajanus cajan*) were used as sources of green manure in improved fallow plots. Control plots used were maize stover and natural weeds as sources of nitrogen. The amounts of time and labour involved in the management of each practice were monitored throughout the growing season. Results indicate that green manures are superior to maize and weeds commonly incorporated by smallholder farmers to improve yields. Management of green manures require more time and labour than of maize stover and natural weeds. Economic importance of the multipurpose tree species and maize in terms of nitrogen contribution to the top soil and maize yields is discussed

Citation: B.C. B Kamanga, G.Y Kanyama-Phiri and S Minae, (1997). Assessment of resource requirement and output potential of soil management technologies in Zomba, Malawi, A paper presented at soilfertnet workshop at Mutare, Zimbabwe 7 - 11 July, 1997



Part 7: Conservation Agriculture

7.1 Improving maize yields with *Tephrosia candida* under conservation agriculture practice

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Food insecurity in Malawi is directly linked to declining soil fertility, with nitrogen being the main limiting factor. The most soils are exhausted such that it has become impossible for smallholder farmers to produce enough food without the use of inorganic fertilizer. A study on the effect of conservation agriculture with trees (CAWT) was conducted in Kasungu, Lilongwe and Salima districts in Central Region. The main objective was to evaluate the effectiveness of on farm agroforestry based CAWT on maize productivity. A total of 9 treatment combinations were assessed for three years (2011, 2012 and 2013) under rainfed. The treatment combination included the use conventional ridges (C), old ridges (O), Basin planting (PB) in combination with fertilizer (F) application and under sowing of *Tephrosia candida* (Tc). The results have shown that of the 9 treatment combinations over the three years, treatment combinations of Conventional ridges + fertilizer (CF) out yielded (5801kg/ha) all the other treatment combinations. Treatment combination in which *Tephrosia candida* was included (CTc, OTc, and PBTc) without fertilizer application yielded the least. It was observed that low quantities of *Tephrosia* leaf were produced due to poor *Tephrosia* stand establishment. In addition, the maize stover quantity was relatively low and not sufficient to ensure adequate soil moisture conservation for subsequent nutrient use efficiency. Site differences also did affect the maize yield performance under same treatments.

Citation: Njoloma J, Sosola B.G, Sileshi G.W, Kumwenda W, and Phiri S, (2014). Improving maize yields with *Tephrosia candida* under conservation agriculture practice, In: Kabambe V, Tembo Y and Ngwira A, editor. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 137

7.2 Effect of conservation agriculture on soil quality and crop production

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Nutrient mining, poor soil tillage practices and over grazing have all lead to the depletion of soil organic matter, the breakdown of the soil structure and increased soil erosion, leaving the land less able to store water, affording the crops little possibility of withstanding the recurring droughts. This has resulted into low crop yield and deteriorating soil health in most soil of the sub-Saharan Africa. Conservation agriculture (CA) has been proposed as a potential system for improving soil quality and providing stable yields through minimum soil disturbance, surface crop residue retention (mulching) and crop rotations or associations. However, the effect of conservation agriculture on soil chemical, physical and other biological properties have adequately been studied, hence, the initiation of the study in an already established CA long term trail, in its 5th season at Chitedze Research Station-Malawi. The main aim of the study was to evaluate the medium term effect of conservation agriculture systems on soil quality and crop productivity. The experiment had a total of eight treatments that aimed at assessing the potential CA cropping systems in comparison to the convention tillage. Soil from different soil depth along the soil profile (0 to 10 cm, 10 to 20 cm, 20 to 30 cm, 30 to 60cm, 60 to 90 cm) from all the five years were analysed for the determination of soil chemical properties. Soil aggregate stability was determined was the soil samples collected in one year of the experiment (2007) and year five (2012). In addition, biological soil properties (earthworm counts) were determined in February, 2012. The results showed that chemical nutrient build up in CA is gradual and the significant differences between treatments on the top soil (0-10 cm) were realized from the year four of practicing CA. In the 5th year pH, SOC, P and K further increased by 0.69-0.89, 77.3-112.5 Mg C ha⁻¹, 10-40 µg/g and 0.05 -0.02 cmol/g respectively in the CA treatments. In contrast, pH, SOC, P and K declined in the convention treatment by 0.51, 32.5 Mg C ha⁻¹, 6 µg/g and 0.13 cmol/kg respectively. Soils from CA treatments were more stable, 61.2 % to 69.4% of the soil particles composed of soil aggregates of greater than 2mm (>2mm) in diameter, while only 30% of the soil particles from the convention tillage had the soil aggregates >2mm by the 5th year. In the top 30 cm of the various CA treatments recorded a range of 35 to 99 earthworms per meter square against 17 earthworms per meter square in the convention treatment. Maize yield became more stable in the 4th and 5th year with CA treatments giving higher yields than the convention treatment. In all cases, CA in a maize cowpea rotation treatment gave highest values. From this study it can be concluded that conservation agriculture improves soil quality and optimizes benefits. Integrated legumes in the Conservation agriculture, either by rotation or intercropping, enhances further soil fertility and crop yields.

Citation: Ligowe S.I, Nalivata P.C, Njoloma J, Makumba W and Thierfelder C, (2014). Effect of conservation agriculture on soil quality and crop production. In: Kabambe V, Tembo Y and Ngwira A, editor. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 91-100

7.3 Benefits and challenges of crop rotations in maize-based conservation agriculture (CA) cropping systems of southern Africa

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Conservation agriculture (CA) based on minimum soil disturbance, crop residue retention, crop rotations and associations are being promoted in southern Africa to reverse the decline in soil fertility and crop productivity. While agronomic benefits of rotations are known, farm level benefits of rotations in CA systems and how they fit in the smallholder farming systems have not been sufficiently addressed. This paper summarizes agronomic results from 2005 to 2011 of maize in rotation and association with different crops in Malawi, Mozambique, Zambia and Zimbabwe. Rotation with or without legumes improved water infiltration (between 70 and 238%), soil moisture, soil carbon, macro-fauna and crop productivity. However, due to poor market conditions, rotations with legumes were less profitable than maize during the study period. Farmers have fewer difficulties to abandon tillage and there is scope to retain crop residues in situ in areas of limited crop–livestock competition but the adoption of rotations and associations is by socio-economic factors that need to be addressed before all principles of CA can be applied.

Citation: Thierfelder C, Cheesmana S and Rusinamhodzi L (2010). Benefits and challenges of crop rotations in maize-based conservation agriculture (CA) cropping systems of southern Africa, *International Journal of Agricultural Sustainability*, 11:2, 108-124

7.4 Enhancing the adoption of conservation agriculture through demand led interactive radio program: a case of Mbwadzulu EPA in Mangochi District.

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Effective and efficient agricultural extension services are a key to ensuring widespread adoption and scaling of CA. Emerging paradigms in agricultural extension services and advisory services attest to the use of radio and mobile phones as critical tools that can be used to further the technologies of transfer to smallholder farmers. In 2014, Farm Radio Trust (FRT) a non-profit organization that provides agricultural extension and advisory services to smallholder farmers partnered with Farm Radio International (FRI) in Canada, to work with Dzimwe Community Radio Station in Mangochi and other partners to offer demand driven radio based extension services on CA to farmers through an 'ICT-enhanced Participatory radio Campaign' as an innovative strategy in the provision of information on climate smart agricultural innovations. FRT used a radio-based model developed by FRI called a 'participatory radio campaign' which is a planned radio activity, conducted over a specific period of time in which a broad population of farmers is encouraged to form an informed decision about adopting a specific improvement selected by their peers, based upon the best available information, to improve food security in their families. A mobile based platform was also used in order to solicit feedback on the radio campaign from the farmers. The campaign ran for 4 months and started radio programs with no unique users who gave the feedback. By the end of the campaign, 878 farmers registered as active contacts who provided feedback on the radio programs. They also mounted and formed radio listener clubs which helped them to access the radio programs and apply what they had learned easily. This project demonstrated that radio and other ICTS can be used to further the transfer of agricultural technologies in Malawi

Citation: Mloza-Banda C. B, Chapota R and Chinkhokwe P, (2015). Enhancing the adoption of conservation agriculture through demand led interactive radio program: a case of Mbwadzulu EPA in Mangochi District, 3rd Biennial Conservation agriculture Symposium and 1st Climate Smart Agriculture Forum 2015, Ministry of Agriculture, Irrigation and Water Development, Lilongwe, Malawi.

7.5 Unearthing the link of conservation agriculture to sustainable food security and agro-aquaculture enterprise: a case for Mthiramanja EPA, Mangochi

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Impacts on hunger and poverty on the Malawi's rural households could be mitigated if conservation farming is widely rolled out over the conventional farming practices. A comparative study assessing the link between conservation agriculture and agro-aquaculture entrepreneurship in Mthiramanja EPA in Mangochi found out that out of 52 percent of farming on conservation agriculture embarked on other farming ventures and their fish ponds sustained water throughout the year unlike the counterparts insisting on conventional farming practices. Conservation agriculture within the scope of integrated agro-aquaculture practice is sustainable and profitable through high water retention, reduced soil erosion, and high organic matter content that enriches and loosens up the soil thereby leading to minimum use of fertilizers and easy workability on the soil. These benefits compounded together easily motivated a farmer to expand into meaningful horticulture and animal husbandry thus guaranteeing an all year round cycle of active entrepreneurship unlike in those conventional agriculture systems. Farmers on conservation agriculture relatively obtained high returns on investment than those on conventional agriculture, therefore such outcomes reaffirm that if conservation farming is adopted nationwide, it would increase the agriculture sector production thereby contributing towards sustainable rural households food and economic security and minimizing the cases of soil erosion.

Citation: Saukani A, (2014). Unearthing the link of conservation agriculture to sustainable food security and agro-aquaculture enterprise: a case for Mthiramanja EPA, Mangochi, In: Kabambe V, Tembo Y and Ngwira A, editor. Proceedings of the first Integrated Soil Fertility Management Symposium, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi, SoHCoM Publication 09: pp. 12-26

7.6 Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa (SIMULESA)

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Conservation agriculture (CA) based exploratory trials were initiated in 2010-11 cropping season. The aim was to develop resilient production with emphasis on intensification of maize and legume associations. The sites were Kasungu, Mchinji and Lilongwe in Mid-altitude while Balaka, Ntcheu and Salima for low altitudes of Malawi. Six different treatments in low altitude and five treatments in the mid-altitudes were tested and each farmer hosted a set of treatment representing a replicate. A total of 36 farmers hosted the trial across six districts. All plots including the farmers check received equal amounts of nitrogen fertilizers (92 kgN/ha). All CA plots were managed within the principles of CA while the farmers check was at liberty to ridge and burn or export crop residues from the production unit. All management was done by farmers with assistance of the extension worker. Data was collected by the extension worker with the help of the established local SIMULESA research committee of the area. Data collected included: weather, soils, agronomic, social and numbers on field days and exchange visits. Results indicate significant differences on maize grain yield in some sites. CA treatments outperformed farmers check. Crop residues effect on weed control performed similar herbicidal effect on weed control. CA based maize legume crop rotations outperformed sole maize treatments. More farmers adopting CA were influenced by exchange visits.

Citation: Kamalongo D., Ligowe I.S, Ngwira A, Nyagumbo I and Wall P, (2015). Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa (SIMULESA), Cereals Commodity Group Experiments and Services Reports for 2014/2015 Crop Season, Department of Agricultural Research Services, Lilongwe, Malawi

7.7 Reflections on agronomic yields, farmer perspectives, out scaling and economic feasibility of Conservation Agriculture (CA) in maize-legume based cropping systems in Malawi

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In Malawi different maize and legume intensification cropping systems under CA were evaluated on farm for two cropping seasons since 2010 through the regional project 'Sustainable Intensification of Maize legume systems in Eastern and Southern Africa (SIMULESA). The main objective of research was to develop and select sustainable

and resilient maize/legume production systems and scale out to farmers through innovation platform. Low and mid altitudes contrasting were targeted for this research. Each agroecology comprised of three districts. In the mid-altitude agroecology districts five similar treatments tested in all districts. Similarly, six treatments were tested in all low-altitude agroecology districts. Key measurements in the study were climatic data, agronomic data, farmers' perception towards treatments under evaluation, outscaling strategies and economic benefits. Across two years of study regardless of treatments and maize variety planted, highest mean maize grain yield of 4435 kg/ha was obtained from mid altitude agroecology and 3841 kg/ha was obtained from low altitude agroecologies. Significant differences ($p < 0.05$) on mean maize grain yield in the first cropping season were influenced by external factors other than treatments e.g. climatic and management factors. Significant differences ($p < 0.05$) observed in Lilongwe in the second year was influenced by treatment effects. In low altitude agroecology lowest mean maize grain yield (3224 kg/ha) was yielded from the farmers check with highest mean yield (3622 kg/ha) from the maize-groundnuts rotation system. In the mid altitude agroecologies, lowest (4099 kg/ha) and highest (4702 kg/ha) mean maize grain yields were obtained from farmers check and maize-soya rotation respectively. In general across agroecologies gross mean yield from all CA based treatments out yielded farmers check. Maize-legume rotation system under CA was favoured most and ranked the best system by farmers. Induced farmers exchange visits and involvement of relevant stakeholder in out scaling of technologies resulted in increased adoption. . Lowest net benefits of 157.0 USD/ha was realized from the farmers check with highest net benefits of 781.3 USD/ha from maize-legume rotation, Mean net benefits of 549.3 USD/ha was realized from all CA treatments over the experimental check (157 USD).

Citation: Kamalongo D, Nyagumbo I, Siyeni D, Kamwana F, Jefias, (2015). Reflections on agronomic yields, farmer perspectives, out scaling and economic feasibility of Conservation Agriculture (CA) in maize-legume based cropping systems in Malawi, Soils and agricultural engineering commodity group project reports (2014/15) and proposals for (2015/16), Department of Agricultural Research Services, Lilongwe, Malawi

7.8 The impact of conservation tillage technology on conventional weeding and its direct effect on the cost of maize production in Malawi

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Declining soil fertility, poor agronomic practices, and low adoption of recommended technologies have been singled out as the main factors constraining production of maize and other crops in Malawi. Sasakawa Global 2000 initiated an agricultural programme aimed at transferring and disseminating recommended agricultural technologies to smallholder farmers. Through partnership with the Department of Agricultural Research Services, several, management training plots were established. These demonstration plots were used by field assistants to train farmers on the management of maize from sowing to storage in the granary. The Sasakawa Global 2000 maize technology advocates that weeding should be done two to three times to ensure that the plot is free from the weeds the first 50 days of the season. The second method introduced to farmers in Malawi in the control of weeds is through the use of zero tillage and chemical weed control (conservation tillage). Yield averaging more than 5 tons per hectare were obtained in the conservation tillage demonstration plots and in the conventional mechanically weeded plots. Farmers were happy with good control of weeds, good maize yields and the saving of labour for weeding.

Citation: Valencia JA and Nyirenda N (2003). The impact of conservation tillage technology on conventional weeding and its direct effect on the cost of maize production in Malawi. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 53-58.

Part 8: Agroforestry

8.1 The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi

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Research conducted in different ecological zones of Malawi indicated that *Acacia albida* has effect on maize similar to those reported in the Sahel, Sudan and Ethiopia. Yield and soil trends were evaluated along the transect lines at increasing distances from individual trees in different orientations extending away from the tree canopy. Explanatory studies along the lakeshore plain of Lake Malawi during the 1987/88 showed that yields of local maize under *A. albida* were more than doubles yield away from the tree. However, the soil fertility changed little over a length of the transect. Later studies were conducted inland from the lake with hybrid and local maize. Soil differences were again minimal. Hybrid maize (NSCM41 and R201) generally out yielded local maize, but the size and the period of sampling were too limited for conclusive results, especially regarding crop sustainability. Overall yield patterns were similar to the lakeshore area, but differences were more variable. This appeared to be the function of variability in the tree size and shape, soil, crop management by the farmer, and proximity to the neighboring trees. The relative contribution of these factors is not known, indicating areas for further research. Because of the on-farm nature of these trials, control over external influences was limited, suggesting the need to standardize cropping practices and other factors across sites if the mechanisms affecting yield were to be understood.

Citation: Saka AR, Bunderson WT, Itimu OA, Phombeya HSK and Mbekeani Y, (1994). The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi, *Forest Ecology and Management* 64: 217- 320

8.2 Adopting Agroforestry: Evidence from Central and Northern Malawi

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This study was conducted in rural central and northern Malawi to (1) identify factors limiting/enhancing agroforestry adoption and (2) assess the impact of cultural differences on the adoption and use of agroforestry systems. The study involved interviewing representatives of large number households concentrated in four separate study areas. The study used the grounded theory method of sociology, which relies on largely qualitative data and inductive reasoning. Nine-tenths of the farmers in the study were resource poor with little or no formal education. Two-thirds of the farmers in the study were not familiar with agroforestry systems such as alley cropping. The level of interest in adopting agroforestry systems, which did not include the application of inorganic fertilizer, was quite high because of anticipated improved crop yields. An overriding theme emerging from the study was the importance of considering micro-level economic conditions and cultural dynamics in the design of successful agroforestry programs. The results also suggest the utility of local level social analysis prior to efforts designed to further promote the adoption of agroforestry. Clearly, biological sustainability is essential, but not sufficient in the design of such programs.

Citation: Blatner Charlie K A, Bonongwe S. L and Carroll M S, (2000). Adopting Agroforestry: Evidence from Central and Northern Malawi, *Journal of Sustainable Forestry*, Vol. 11(3), pp. 41-69.

8.3 Agroforestry adoption in southern Malawi: the case of mixed intercropping of *Gliricidia sepium* and maize

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Agroforestry, now considered as a sustainable agricultural system, is being widely promoted all over the world especially in sub-Saharan Africa. This paper investigates the adoption of mixed inter-cropping an agroforestry tree species, *Gliricidia sepium*, and maize in Malawi. The differences between adopters and non-adopters of *Gliricidia sepium* in terms of their age, active members of the family, extension contact, income sources and other

socioeconomic variables are examined. Results from logistic regression analysis suggest that age of the farmer, extension contact and the number of people who contribute to farm work are important variables in determining the adoption of agroforestry. It was observed that farmers modified technologies to suit their situation, suggesting that local participation is important in technology development.

Citation: Thangata P.H, Alavalapati J.R.R, (2003). Agroforestry adoption in southern Malawi: the case of mixed intercropping of *Gliricidia sepium* and maize, *Agricultural Systems* 78, pp. 57–71.

8.4 Farmer participatory assessment of two researcher managed ‘fertilizer tree systems in Southern Malawi

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The suitability of maize under two fertilizer tree fallow systems were evaluated by farmers at Makoka Agricultural Research Station in southern Malawi. Sixty-eight farmers drawn from five farmer groups assessed *Gliricidia*-maize intercropping system, and 72 farmers assessed rotational fallows with 10 trees species during 2001. Fertilizer treatments and maize plots served as controls. *Gliricidia*-maize plot without fertilizer amendment and maize fertilized with 50% of the recommended N dose in *Gliricidia*-maize intercropping were judged as “best” by the majority (60-71%) of farmers involved in assessing the technologies in groups as well as individuals. Among the rotational fallows, the majority of farmers had ranked maize cropped after *Tephrosia vogelli*, *Gliricidia sepium* and *Sesbania sesban* higher than with fertilized monoculture maize. The unfertilized maize plot was adjudged unsuitable by 96% of the farmers. Maize plots supplied with 50% of the recommended N dose were less preferred to unfertilized *Gliricidia*-maize plots

Citation: Akinnifesi F. K, Makumba W, Sileshi G. W and Ajayi O. C, (2009). Farmer participatory assessment of two researcher managed ‘fertilizer tree systems in Southern Malawi, *African Journal of Agricultural Research* Vol. 4 (4), pp. 269-277

8.5 Integration of legume trees in maize-based cropping systems improves rain use efficiency and yield stability under rain-fed agriculture

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Water availability is a major constraint to crop production in sub-Saharan Africa (SSA) where agriculture is predominantly rain-fed. This study aimed to investigate the effect of the nitrogen-fixing legume tree *Leucaena* (*Leucaena leucocephala*) and inorganic fertilizer on rain use efficiency (RUE), a robust measure of productivity and land degradation, in three long-term (11–12 years) experiments conducted in Zambia and Nigeria. On the two Zambian sites, sole maize (*Zea mays*) grown continuously (for 11–12 years) with the recommended fertilizer achieved the highest RUE (3.9–4.6 kg ha⁻¹mm⁻¹) followed by maize intercropped with *Leucaena* (2.5–3.4 kg ha⁻¹mm⁻¹). This translated to 192–383% increase in RUE over the control (maize grown without nutrient inputs), which is the de facto resource-poor farmers’ practice. RUE was more stable in fully fertilized sole maize on the first Zambian site and not statistically different from the maize–*Leucaena* associations on the second site. On the Nigerian site, RUE was higher in maize planted between *Leucaena* hedgerows supplemented with 50% of the recommended fertilizer (3.9 kg ha⁻¹mm⁻¹), maize grown between *Leucaena* hedgerows without fertilizer (3.0 kg ha⁻¹mm⁻¹) and sole maize receiving the recommended fertilizer (2.8 kg ha⁻¹mm⁻¹), which translated to increases in RUE of 202%, 139% and 85%, respectively, over the control. RUE was more stable in the maize grown between *Leucaena* hedgerows than in the fully fertilized maize. On all sites RUE was least stable in the control. Yield stability in the maize–*Leucaena* association was not significantly different from the fully fertilized maize on the Zambian sites. On the Nigerian site, maize yields were more stable in maize grown in *Leucaena* hedgerows than in fully fertilized sole maize. Supplementation of maize grown in *Leucaena* hedgerows with 50% of the recommended fertilizers resulted in greater yield stability. It is concluded that intercropping cereals with legume trees and supplementation with inorganic fertilizer can increase rain use efficiency and yield stability in rain-fed agriculture in SSA.

Citation: Sileshi GW, Akinnifesi FK, Ajayi OC, Muys B (2011). Integration of legume trees in maize-based cropping systems improves rain use efficiency and yield stability under rain-fed agriculture, *Agricultural Water Management* 98, pp.1364– 1372

8.6 Assessing soil fertility status for fertilizer tree targeting in selected sites in Mzimba, Dedza and Thyolo districts

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The biophysical survey was conducted in the AFSP II implementing districts, namely Mzimba, Dedza and Thyolo. The overall objective of this survey was to document the current soil characteristics in the project implementation sites on which changes in the soil properties and crop productivity impacts of the agroforestry interventions will be assessed. A total of 33 participating farmers' fields were sampled from which soil samples were collected at two depths 0-20cm and 20-50cm using an auger. The collected soil samples were analysed to determine their current soil physical and chemical properties. The results revealed that the soils in all the implementing sites are slightly acidic with most of the sites having the pH<5.5. Soil organic matter is very low and this has contributed to the low and moderate levels of organic carbon, N, P, and K in most of the sites. The overall soil fertility status in all the implementing sites is too low for most of the crops a farmer can grow. Sustainable soil fertility management practices including conservation agriculture and intercropping with fertilizer trees have the potential to rebuild the soil fertility resource base.

Citation: Njoloma JP, Sosola BG, Nalivata PC, Njoka BI and Sileshi GW (2015). Assessing soil fertility status for fertilizer tree targeting in selected sites in Mzimba, Dedza and Thyolo districts, 3rd Biennial Conservation agriculture Symposium and 1st Climate Smart Agriculture Forum 2015, Ministry of Agriculture, Irrigation and Water Development, Lilongwe, Malawi.

8.7 Undersowing maize with *Sesbania sesban* in Southern Malawi: tree growth, biomass, yields and maize responses to N source at three landscape positions

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Many soil of sub-Saharan Africa are depleted of soil organic matter, an importance of source of organic nitrogen and phosphorus. This organic matter depletion arises largely from the continuous maize cultivation on small land holdings. The situation is usually aggravated by high human population pressure which forces farmers to cultivate on steep and fragile slopes that are vulnerable to runoff and soil erosion. The objectives of this study were (1) to determine growth, survival, biomass and quality of *Sesbania* at three landscape positions, and (2) to assess agronomic yields in maize response to nitrogen sources and landscape positions. An on-farm experiment consisted of three landscape positions combined factorially with three nitrogen sources in a Randomized Complete Block Design involving 40 farmers who served as blocks (replicates). The three landscape positions were valley bottom (0-12%), dambo margins (0-12%), and steep slopes (>12%). *Sesbania sesban* and CAN served as organic and inorganic N sources, respectively, while the control treatment received no external source of N. Plant survival, number of primary branches per plant, stem diameter, leafy and woody dry matter yields and stack volume of *Sesbania* were significantly different at three landscape positions, as was maize grain yield. Maize grain yield from inorganic source of N was significantly higher ($P<0.05$) than maize yield from the control source though not significantly different from the organic source. These results indicate that there is potential for tree legumes to contribute to soil fertility under relay intercropping of maize and *Sesbania sesban*.

Citation: A. D Phiri, G.Y Kanyama-Phiri and S. S Snapp, (1997). Undersowing maize with *Sesbania sesban* in Southern Malawi: tree growth, biomass, yields and maize responses to N source at three landscape positions, Proceedings of the Soil Fert Net Results and Planning Workshop Held from 7 to 11 July 1997 at Africa University, Mutare, Zimbabwe, 312 pp.

8.8 The effects of *Acacia albida* on soil and maize yields under smallholder far conditions in Malawi

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Research conducted in different ecological zones of Malawi indicates that *Acacia albida* had effects on maize similar to those reported in Sahel, Sudan and Ethiopia. Yields and soil trends were evaluated along transect lines at increasing distances from the individual trees in different orientations extending away from the tree canopy. Explanatory studies along the lake shore of Lake Malawi during the 1987/1988 season showed that yields of local maize under traditional management with *A. albida* were more than double the yield away the trees. However, the soil fertility status changed little over the length of the transects.

Later studies were conducted inland from the lake with local and hybrid maize. Soil differences were again minimal. Hybrid maize (NSCM 41 and RM 201) generally out yielded local maize, but the size and period were limited for conclusive results, especially regarding crop sustainability. Overall yield pattern were similar to the lakeshore area, but differences were more variable. This appeared to be a function of variability in tree size and shape, soils, crop management by the farmer, and proximity to the neighboring trees. The relative contributions of these factors are not known, indicating areas for further research. Because of the on-farm nature of these trials, control over external influences was limited, suggesting the need to standardize the cropping systems and other factors across sites if the mechanisms affecting yields to be better understood.

Citation: Saka AR, Bunderson WT, Itimu OA, Phombeya HSK and Mbekeyani Y (1994). The effects of *Acacia albida* on soil and maize yields under smallholder far conditions in Malawi, *Forest Ecology and Management* 64, pp.217-230

8.9 Maize production under tree-based cropping systems in Southern Malawi: A cobb-Douglas approach

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A study was conducted in Zomba, southern Malawi in 1996-98 to evaluate the potential of tree-based green systems to increase maize yields. Using the data collected from the study, a Cobb-Douglas maize production function was estimated with particular interest in the technical relationship between maize yield and the inputs (fertilizer and labour). Ordinary Least Squares regression techniques were used to perform the analysis. Return to scale and elasticities of the inputs were estimated from the production function. Gross margins were analysed to give a relative indicator of profitability and food supply to the households. Results indicated that fertilizer, land and labor are significant factors of production in maize-legume based interplanting. The estimated coefficients for the input factors (a) were non-negative (1.16, 0.21 and 0.14 for labour, land and fertilizer, respectively) indicating increased marginal productivity to the inputs. Returns to scale in all landscape positions show increasing returns that were significant at $P=0.05$. Gross margin analysis showed that legume green manure with addition of 48kg N ha⁻¹ gave higher returns to labour (MK9.60 Mnh⁻¹) seconded by pigeon pea-based system (MK8.90). These results suggests that interplanting of maize with legumes increases maize yields. However, it is necessary to devise ways of saving labour and land so as to maintain or increase maize production per unit land.

Citation: Kamanga BCG, Kanyama-Phiri GY and Minae S (2000). Maize production under tree-based cropping systems in Southern Malawi: A cobb-Douglas approach, *African Crop Science Journal* 8 (4): 429-440

8.10 Maize yield response to different amounts of applied water at different levels of applied nitrogen for 1992 cropping season

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This experiment was conducted at Kasinthula Agricultural Research Station in the 1992 dry season. Irrigation treatment ranged from 20 percent to 120 percent at intervals of 20 percent of estimated maize evapotranspiration. The estimated E_t was treated as the 100 percent amount. Nitrogen treatments were: 0, 80 and 160 kg/ha. The treatments were factorially laid out in a Split Plot Design with four replicates. Nitrogen levels were main plots and levels of applied water were subplots. Irrigation was scheduled using the soil moisture balance system. The crop was irrigated at 50 percent depletion of the available water in the 100 percent treatment. The method of irrigation was furrow using a gated 10-cm diameter PVC pipe. Results showed that maize grain yield did not respond to the increasing amount of applied water at 0 kg of applied nitrogen per hectare. There was a significant positive quadratic relationship ($P \leq 0.05$) between grain yield and ear height; and water at 160 kg of applied nitrogen per hectare. There was, however, a significant positive relationship ($P \leq 0.05$) between grain yield, ear height and all the other measured maize agronomic variables; and applied water at both 80 and 160 kg of applied nitrogen per hectare. These results showed that applied nitrogen was important for maize to respond positively to water

Citation: Kauta GJC and Kadwa FE (1992). Maize yield response to different amounts of applied water at different levels of applied nitrogen for 1992 cropping season, Technical Report, Kasinthula Agricultural Research Station, Chikwawa, Malawi

8.11 Evaluation of *Gliricidia sepium* provenances for alley cropping in Malawi

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Nine provenances of *Gliricidia sepium* were evaluated to identify the most productive when under alley cropping at Kawinga in Machinga, Malawi. Individual provenances constituted plots arranged in randomized block design with six replications. One year after establishment survival of the provenances ranged between 82 and 97%, whereas height diameter varied between 1.6 and 2.2 m and 16.7 and 23.5 mm respectively. Wood basic density ranged between 393 and 450 kg/ha per year. Foliar nutrient content varied from 2.58 to 3.15 % (magnesium) and 0.04 to 0.05% (sodium). Although biomass production between the provenances varied significantly only at certain lopping stages within provenance variations were noticed throughout in the traits assessed. Such variations indicate that both provenance and individual tree selection method can be used for the genetic improvement of *G sepium* for specific agroforestry uses. The overall most provenances were Rotalhuleu (14/84), Pontezuela Bolivar (24/86), Volam Suchitan (13/85) provenances. These provenances are therefore recommended for further testing to address appropriate agroforestry requirements in different agroecological zones.

Citation: Ngulube MR (1994). Evaluation of *Gliricidia sepium* provenances for alley cropping in Malawi, *Forest Ecology and Management* 64, pp.191-198

8.12 Contribution of *Tithonia diversifolia* to yield and nutrient uptake of maize in Malawian small-scale agriculture

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Locally available non-traditional green manure plants could potentially contribute to reversing the trend of declining soil fertility and raise maize yield in small-scale farms. In this study, *Tithonia diversifolia* was tested as a low cost green manure in Malawi. In a greenhouse incubation experiment, changes in soil nitrate (NO_3^-), ammonia (NH_4^+) and extractable phosphorus (Mehlich-3 P) were compared between treatments of *T. diversifolia*, *Crotalaria jucea* (sunhemp), *Tephrosia vogelii*, *Mucuna utilis* (velvet beans) and maize stover that were applied to the soil at an equivalent rate of 3 Mg dry matter /ha. This was followed by a field study where three rates of *T. diversifolia* dry matter (1.5, 3.0 and 4.5 Mg /ha) were applied with or without triple superphosphate (TSP) supplement to maize grown at three locations in central and northern Malawi. The changes in laboratory incubated soil NO_3^- , and NH_4^+ , were similar among *T. diversifolia*, *Tephrosia* and *Mucuna* while the change in soil treated with maize stover was less and similar to that observed in bare soil. The greatest change in soil NO_3^- , and NH_4^+ levels were induced by *Crotalaria*. In the field, the average maize yields were 4.6 Mg /ha at Chitedze, 3.1 Mg /ha at Bembeke and 1.1 Mg /ha at Champhira. The lowest *T. diversifolia* rate (1.5/ha), increased maize yield over that obtained in the control plot by 41% at Bembeke, 122% at Chitedze and 162% at Champhira. Maize yields increased with increasing *T. diversifolia* rates and yields obtained with 3.0 and 4.5 Mg *T. diversifolia* /ha were similar to those obtained with 90 Mg N /ha as inorganic fertilizer. There was no obvious benefit from supplying TSP in combination with *T. diversifolia*. Given the nutrient release and maize yield values with *T. diversifolia*, it should prove to be a good green manure that can be afforded by small-scale farmers in these regions of Malawi.

Citation: Ganunga RP, Yerokun OA, and Kumwenda JDT (2000). Contribution of *Tithonia diversifolia* to yield and nutrient uptake of maize in Malawian small-scale agriculture, *S.Afr. Tydskr. Plant. Grond* 22 (4), pp. 240-245

8.13 Undersowing maize with *Sesbania sesban* in southern Malawi: 2. Nitrate dynamics in relation to N source at three landscape positions

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A study was conducted in 40 farmers' fields in Zomba Rural Development Project, southern Malawi to measure nitrate-N dynamics in different landscape positions as influenced by N sources. The landscapes were the dambo margin, valley bottom and steep slopes. Nitrogen sources consisted of an inorganic fertilizer, organic fertilizer and a control. The inorganic plot received 120 kg N /ha. The organic fertilizer plot was a relay intercropping system of *Sesbania sesban* biomass applied at the rate of 500-300kg /ha, depending on tree grown the previous year. Nitrate availability varied across the maize growing season. The highest nitrate levels (16 mg/kg) were observed at 85 days after maize planting (DAP) and decreased markedly (7 mg/kg) towards the end of the growing season. There were no significant differences in topsoil nitrate among the tree landscape positions. However, nitrate in the subsoil was consistently highest at the valley bottom site and lowest at the steep slope. This was expected due to higher soil organic C and total N at lower landscape positions sites compared to eroded slopes. There was greater nitrate accumulation in the N input plots (both inorganic and organic) than zero N control.

Similarities in nitrate dynamics in the top soil over the season suggested similar release pattern from organic and inorganic sources. In the subsoil, by contrast, nitrate at the end of the growing season accumulated 2-fold higher in the inorganic N treatment than any other treatment (12 mg/kg compared to about 5 mg/kg). This was in part due to higher N inputs in the fertilizer treatment. Subsoil nitrate accumulation indicated the potential for nitrate leaching with use of inorganic N fertilizer, particularly for valley bottom sites.

Citation: A. D Phiri, G.Y Kanyama-Phiri and S. S Snapp, (1997). Undersowing maize with *Sesbania sesban* in Southern Malawi: tree growth, biomass, yields and maize responses to N source at three landscape positions, Proceedings of the Soil Fert Net Results and Planning Workshop Held from 7 to 11 July 1997 at Africa University, Mutare, Zimbabwe, 312 pp.

8.14 *Tithonia diversifolia*: an organic source of nitrogen and phosphorus for maize in Malawi

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We conducted trials in Malawi to test the suitability of leaves from *Tithonia diversifolia* as an organic source of nitrogen and phosphorus in Malawi. The application of *Tithonia* leaves gave maize grain yields that were significantly higher than a no fertilizer treatment. The application of *Tithonia* leaves at 1.5 t/ha produced maize grain yields that were 39% over the control at Bembeke, 122% at Chitedze and 162% at Champhira. *Tithonia* leaves applied at 1.5 t/ha produced maize grain yields that were 12% higher than the standard fertilizer rate at Chitedze but were 24% lower at Bembeke and 30% lower at Champhira. Supplementation of TSP to *Tithonia* did not result in significant maize yield increases compared to the application of *Tithonia* leaves alone. There were no significant maize grain yield differences among the *Tithonia* treatments at Chitedze and Bembeke.

Citation: Ganunga R, Yerokun O and Kumwenda JDT (1998), *Tithonia diversifolia*: an organic source of nitrogen and phosphorus for maize in Malawi, Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

8.15 Preliminary findings of the adoption of agroforestry technologies by smallholder farmers in Zomba, Malawi

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This paper discusses preliminary findings of a study investigating the potential for adoption of agroforestry technologies by smallholder farmers in Zomba Rural Development Project (RDP). Participatory methods used in the study including the village group discussions, resource mapping, linear transect sampling and farmer interviews. Findings on land characteristics such as slopes, and holding size; trees grown on the holding, including agroforestry species; and farmers' knowledge and experience of implementing agroforestry technologies are presented. Major farmer problems are identified as: land shortage, food insecurity, declining soil fertility, unaffordable inorganic fertilizers and labor shortages, particularly among female-headed households. Finally various technologies and policy solutions are considered, focusing on those related to agroforestry. Some of these will be conducted in the next phase of the project.

Citation: G.Y Kanyama-Phiri, K Wellard and J.B Kamangira, (undated). Preliminary findings of the adoption of agroforestry technologies by smallholder farmers in Zomba, Malawi, Technical report, University of Malawi, Bunda College of Agriculture

8.16 Evaluation of *Gliricidia sepium* provenances for agroforestry in Malawi

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Gliricidia sepium is gaining considerable attention as a multi-purpose species of good potential for agroforestry in Malawi. A provenance evaluation trial containing 21 seed sources from 8 Central American countries was established at Naungu, Malawi, in December, 1987, to select suitable provenances for use in Malawi. When assessed at age two years, significant variations existed among the provenances among the branching habits and biomass but not in survival, growth, number of stems and density. Within-provenance variations were noticed in all the traits assessed, indicating that both provenance and individual tree selection methods can be used in the genetic improvement of *G. sepium* for specific agroforestry purposes. Managua (31/84), Volcan Suchitan (13/84), Retalhulea (14/84), Guayabillas (24/84) and Masaguara (25/84) provenances were the most outstanding, and are recommended for use and further genetic improvement work in Malawi.

Citation: Ngulube MR and Mwabumba L (1995). Evaluation of *Gliricidia sepium* provenances for agroforestry in Malawi, International Tree Crops Journal 8, pp. 1-11

8.17 The impact of policy and land tenure on agroforestry adoption and development

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Soil fertility decline is a major problem affecting agricultural productivity and development in many sub-Saharan African (SSA) countries. This problem has been worsened in the wake of increasing real prices of the intermediate inorganic inputs which are annually applied to replenish soil fertility. While the continuous decline in the soil fertility is a result of cultivation practices, the application of inorganic fertilizers is also declining due to lack of adequate purchasing power among most farmers. Soil fertility research however, shows that adoption of agroforestry technologies could ensure sustainable agricultural productivity with minimal or no use of inorganic inputs. Although agroforestry provides the scope for agricultural productivity due to the fact that they are less costly to establish and therefore less risky relative to inorganic fertilizers, farmers' adoption of these technologies is still very low. Among other confounding factors, policies that are being pursued do in fact affect farmers' attitude towards agroforestry and thus their willingness to take up agroforestry technologies. This paper highlights a number of agricultural and other sectoral policies that are seen to have an impact on agroforestry adoption and development.

Citation: Tchale H and Lunduka R (2000). The impact of policy and land tenure on agroforestry adoption and development. A Paper prepared for the Training of Trainers Course in Southern Africa, Bunda College of Agriculture, Lilongwe, Malawi

8.18 Dry-season sesbania fallows and their influence on nitrogen availability and maize yields in Malawi

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Nitrogen deficiency is widely spread in southern Africa, but inorganic fertilizers are often unaffordable for smallholder farmers. Short duration leguminous fallows are one possible means of soil fertility restoration. We monitored pre-season topsoil (0 to 20 cm) ammonium and nitrate, fallow biomass production and grain yield for three years in a relay cropping trial with *Sesbania sesban* (L) Merr and maize (*Zea mays* L). *Sesbania* seedlings were interplanted with maize during maize sowing at 0, 7400 or 14, 800 trees/ha, in factorial combination with inorganic fertilizer at 0 or 48 kg N/ha (half the recommended rate) after maize harvest, fallows were allowed to grow during the seven-month dry season, and were cleared before the next maize crop. Both *Sesbania* fallows and inorganic fertilizer resulted in significantly greater ($P < 0.01$ to 0.05) pre-season topsoil nitrate N than following unfertilized sole maize. In plots receiving no fertilizer N, pre-season topsoil inorganic N correlated with maize yield over all three seasons ($r^2 = 0.62, p < 0.001$). *Sesbania* planting density, and were inconsistently related to soil N fractions and maize yields. Short-duration fallows may offer modest yield increases under conditions where longer duration fallows are not possible. This gain must be considered against the loss of pigeonpea (*Cajanus cajan* L. Millsp) harvest in the similarly structured maize-pigeonpea intercrop common in the region.

Citation: Ikerra S.T, Maghembe J.A, Smithson P.C, and Buresh R.J, (2001). Dry-season sesbania fallows and their influence on nitrogen availability and maize yields in Malawi, *Agroforestry Systems* 52, pp. 13-21

8.19 Decomposition and nitrogen use efficiency of high quality tree prunings and low quality crop residues in agroforestry systems

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Crop yields are low in agroforestry systems due to asynchrony between nutrient release by the organic materials and nutrient demand by the crop. The decomposition and N release patterns of high quality tree prunings (*Gliricidia* and *Sesbania*) and crop residues (pigeonpea leaves and roots, and maize stover) were studied in agroforestry systems. The experiment was arranged in a 3 x 6 factorial, the high quality levels were: no tree prunings (NTP), *Gliricidia* (Bs) and *Sesbania* (Ss), and the crop residues levels were: no crop residues (NCR), pigeonpea leaves (Pea-L), pigeonpea leaves + roots (Pea-LR), pigeonpea roots (Pea-R) and two rates of maize stover (-stover-1 and stover-2), maize grain yield and N uptake of Gs/Pea-L, Gs/Pea-LR, Ss/Pea-L, and Ss/Pea-LR treatment were not statistically different from Gs/NCR and Ss/NCR during the two seasons. Mixtures of tree prunings with 2.5 t/ha maize stover increased maize N uptake and grain yield whereas 5 t/ha maize stover had reduced during the wetter season.

Mixtures of Pea-R, Stover -1 or stover -2 with tree prunings depressed yields during the drier seasons. Stover-2 had the highest N fraction immobilized N, 15% and 35% N during the wetter and drier conditions respectively. We conclude that (1) mixing of high quality tree prunings with crop residues may enhance the decomposition of low quality crop residues but there is no special interaction, (2) remineralization of N immobilized early in the season by the low quality organic materials is limited by well distributed rainfall.

Citation: Makumba W and Akinnifesi FK (undated), Decomposition and nitrogen use efficiency of high quality tree prunings and low quality crop residues in agroforestry systems, Technical Report, ICRAF, Chitedze Agricultural Research Station

8.20 Participatory evaluation of maize crops in fertilizer tree systems in Southern Malawi

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Fertilizer trees are self-sustaining soil fertility replenishment technologies built on two decades of on-station and on-farm research and up-scaling initiatives helping hundreds of thousands of farmers to meet their food security needs in southern Africa. This study assessed farmers' perceptions and preferences of a range of inorganic fertilizer and fertilizer tree systems established as an on-station trial. Sixty-eight farmers (including 27 women) from five farmer groups drawn from five Extension Planning Areas (EPAs) and sixteen villages in the southern Malawi were invited to Makoka Agricultural Research Station to participate in the study. The results showed that most farmers preferred maize grown with unfertilized *Gliricidia sepium* as source of soil amendment. Positive synergies when *Gliricidia* was combined with half or quarter of the recommended fertilizer dose, were also noted in farmers' ranking. However, farmers' preferences showed that these additive benefits of chemical fertilizers were less important than the high cost of, and the unavailability of, inorganic fertilizers. There was no significant gender preference by farmers. These findings suggest that, de facto, where low-cost, low risk and sustainable, agroforestry options are clearly demonstrable, the positive yield effect of inorganic P fertilizer has added benefit compared to application of either *gliricidia* prunings or inorganic P fertilizer alone.

Citation: Akinnifesi F.K, Makumba W, Ajayi O.C and Sileshi G, (undated), Participatory evaluation of maize crops in fertilizer tree systems in Southern Malawi, Technical Report, ICRAF, Chitedze Agricultural Research Station, Lilongwe, Malawi.

8.21 Managing fodder trees as a solution to human-livestock food conflicts and their contribution to income generation for smallholder farmers in Southern Africa

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Livestock production is an integral part of smallholder farming systems in Southern Africa. While goats and sheep play some role in the smallholder farmer household economy, cattle are predominant livestock species supplying draught power, milk, manure and meat. Production of cattle is based on traditional range grazing. However, the nutritive value of the range is generally low depending on vegetation types and season. With rapid increase in human population in southern Africa and increasing need to produce staple food on a sustainable basis, smallholder farmers are increasingly encroaching onto marginal lands formerly reserved for cattle grazing. Therefore, cattle subsisting on range require supplementation. Conventional bought-in supplements are expensive. Fodder trees and shrubs have been integrated within some farming systems of Southern Africa as fodder banks with varying degrees of success. Case studies are taken from Tanzania, Malawi and Zimbabwe to provide evidence on how the fodder tree technology has impacted on livestock production with special reference to smallholder dairy production, human food production and smallholder farmers' income. For the wider adoption of the technology, a synopsis of the different scaling up pathways and approaches adopted by research and development is presented.

Citation: Chakeredza, Hove S, L, Akinnifesi F.K, Franzel S, Ajayi O, and Sileshi O, (undated), Managing fodder trees as a solution to human-livestock food conflicts and their contribution to income generation for smallholder farmers in Southern Africa, Technical Report, ICRAF, Chitedze Agricultural Research Station

8.22 Nutrient balances in two agricultural watersheds in Southern Malawi

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Malawi soils are highly depleted resulting in severe food shortages. The study investigates nutrient fluxes into and from the small agricultural watersheds in Southern Malawi. Nutrient balances for N, P and K are calculated in two watersheds (Matipa and Kawanula). Data were obtained on the use of mineral fertilizers, animal manure and crop residues using household interviews. Biological N Fixation was estimated from the measures N uptake, while stream flow losses were calculated from the sediments and soluble nutrient concentrations measure in streams. Wet atmospheric deposition and gaseous losses were estimated based on the data from the study. Estimated annual nutrient balances were 45 N, 16 P and -1 K kg/ha ha/year for Matipa and 25 N, 5P and -5 K kg/ha/year for Kawanula. The positive nutrient balances for N and P were attributed to nutrient importation through mineral fertilizers importation through mineral fertilizers outstripping nutrient export. The comparatively low N losses through stream flow for Matipa and Kawaula (10-15 kg/ha/year) based on discharge, supported the hypothesis that a significant portion of eroded and leached nutrients are redistributed in lower sloped rather than being entirely exported from the watershed. Using an alternative farm balance approach, erosion estimated of 25 kg N/ha/ year for each watershed and leaching losses of 35-42 kgN/ha/year and negative N balances of -32 and -46 kg N/ha/ year for Matipa and Kawanula. The watershed approach may provide opportunities for farmers to judiciously manipulate nutrient flows to achieve a positive nutrient balance.

Citation: Harawa R, Lehman J, Kroma M, Akinnifesi F.K, Sileshi G, Femands E.C.M and Kanyama-Phiri G.Y, (2009). Nutrient balances in two agricultural watersheds in Southern Malawi, *Agricultural Journal* 4 (3), pp. 150-160

8.23 Trees on farms in Malawi: Private Investment, Public policy, and farmer choice

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Agricultural intensification in Malawi has preceded at the expense of the country's extensive woodlands. Rather than clear their farmlands of all trees however, farmers plant or leave preferred species in fields and around households. A number of indigenous and exotic agroforestry species are being promoted through extension. An analysis of potential capital and management costs vis-à-vis increases potential production of local and hybrid maize shows that investment in the tree planting are most favorable when involve low costs and low risks. In order to reduce the farmers' costs of tree planting, the government introduced a Tree Planting Bonus scheme which has provided cash payments as incentives for farmers to plant trees. The program has been costly to administer and has had limited impact. Survey data suggests that existing markets for poles and wood products probably provide better tree planting incentives. Planners need to carefully consider household resource allocation processes with regard to trees and tree based products before they can expect to achieve a significant increase in encouraging rural afforestation.

Citation: Dewees PA (1995). Trees on farms in Malawi: Private Investment, Public policy, and farmer choice, *World Development* 23 (7):. 1085-1102

8.24 Economics of maize- based improved fallow agroforestry systems for smallholder farmers in Central Malawi

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A study was conducted in Kasungu, Central Malawi to assess the economic performance of a short improved fallow agroforestry technology involving *Sesbania sesban*, *Tephrosia vogelii* and inorganic fertilizers. Four maize production systems (*Sesbania* fallow, *Sesbania* + 50% fertilizer, Full fertilizer and Zero input) and two fallow options (*Sesbania* and *Tephrosia*) were compared in terms of contribution to soil fertility, maize yield and economic returns based on farm trial conducted from 1997/98 to 2000/01 growing seasons. The study revealed that *sesbania* gave higher returns to investment compared to the remaining fallow options. The *Sesbania* option had the highest net value followed by the mixed input, full fertilizer and zero input option, respectively. The results also revealed that the combination of organic fertilizer and *sesbania* produced maize yield comparable to the full fertilizer system but at a reduced cost. The difference between the systems with and without *Sesbania* was over 3.5 times.

Sensitivity analysis at 20% on the market prices of the fertilizer and maize grain had a considerable effect on the performance of the systems. Therefore, in maize production, farmers would derive greater economic benefits from using short term fallows in isolation or with fertilizer supplementation.

Citation: Nyirenda M, Kanyama-Phiri GY, Mangison J, Bohringer A and Haule C (2004). Economics of maize-based improved fallow agroforestry systems for smallholder farmers in Central Malawi, *Bunda Journal of Agriculture, Environmental Science and Technology* 2, pp. 49-57

8.25 Agroforestry research and development in southern Africa during 1990s: Review and challenges ahead

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The international Centre for Research in Agroforestry (ICRAF) initiated in 1987 the Southern Africa Agroforestry Programme in partnership with the national research systems in Zomba, Zambia, Zimbabwe and Tanzania to address the problem of low soil fertility and the consequently low crop and livestock production, low cash income, and low shortage of fuelwood and timber that are common to the most rural households in the region. This paper synthesizes the agroforestry research and development during the 1990s from a region perspective and emphasises the scaling-up of promising technologies. The problem of nutrient depletion can be overcome by the use of nutrient fixing and fast growing tree/shrub species, such as *Sesbania sesban*, *Tephrosia vogelii* and *Gliricidia sepium*, as short duration planted fallows in rotation with fallows. Intercropping of food crops with coppicing trees, annual relay intercropping and biomass transfer technologies were found to be appropriate for soil improvement under specific conditions. Tree fodder banks greatly increase fodder production and enrich livestock diet with protein supplements. Rotational woodlots were developed to meet fuelwood and timber demand and reduce pressure on natural woodlands. Research has identified a number of indigenous fruits in the region to supplement the food needs in the rural families, improve their nutritional status and generate cash income. Achieving the ultimate goals of ensuring food security, alleviating poverty and sustaining the environment will require a massive scaling up of adoption of these agroforestry technologies. Key strategies to accomplish this include: increasing the benefits and targeting of agroforestry technologies (for example, through providing substitutes for costly inputs, improving diversification, marketing and processing of agroforestry products, and employing GIS-based targeting techniques) and information-sharing, training and collaborative partnerships in implementation and dissemination of agroforestry options with all major stakeholders (farmers, non-governmental organizations, extension services, education institutions and policy makers).

Citation: Kwesiga K, Akinnifesi FK, Mafongoya PF, McDemott MH and Agumya A (2003). Agroforestry research and development in southern Africa during 1990s: Review and challenges ahead, *Agroforestry systems* 59, pp. 173-186

8.26 Osmosis or project activity? The spread of agroforestry in Malawi

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Unlike a number of technologies and crops introduced into Africa in the past, agroforestry initiatives intended to improve soil quality are not spreading from farmer to farmer. This paper reveals reasons for this failure in Malawi and describes current activities aimed at remedying this situation. African small-scale farmers have shown eagerness to adopt innovations which they see as offering obvious benefits. In many of the continent many farmers mainly plant crops which have been introduced from America together with exotic trees from various parts of the world. They have also adopted new technologies such as ox-ploughing and in the use of inorganic fertilizers. Most of this rapid spread of new crops and technology has been by a process of 'osmosis' from farmer to farmer with little or no formal extension. Why then are agroforestry technologies for improving soil quality not spread in the same way? The reasons include faulty technology, a lack of appreciation of farmers' labour constraints and the absence of the striking short term impact on productivity. The response to this situation has been the development of more appropriate technologies and the intensification of formal extension. As a result there has been increased uptake of technology by farmers associated with projects but little osmotic spread. Fresh initiatives are now needed which make greater use of the extension informal networks that exist in the Malawian rural sector.

Citation: Carr SJ (2002). Osmosis or Project Activity? The Spread of Agro-forestry in Malawi, Proceedings of the Regional Agro-forestry Conference, ICRAF, Lilongwe, Malawi.

8.27 Technical efficiency of relay cropping agroforestry technology: a case of Zomba district in Malawi

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Despite the potential of agroforestry to improve maize production, not much economic agroforestry research has been done in Malawi. A study was conducted in Zomba district on 74 farmers practicing relay cropping and 120 non-adopters of agroforestry to assess technical efficiency and to determine the effect of the technical efficiency on maize production in the district. The study applied Stochastic Frontier Production Model (SFPM) of parametric approach specified by Battese and Coelli (1995) to evaluate the technical efficiency and Two Stage Least Squares Model to determine the relationship between technical efficiency and maize production. The results showed that mean technical efficiencies of relay cropping and non-adopters were 0.50 and 0.46, respectively, implying that there were technical inefficiencies in both categories of farmers. The Two Stage Least Squares Model results showed that technical efficiency affects maize production among the farmers. Thus, although relay cropping was relatively more efficient, farmers in both categories did not realize the maximum possible maize output because they did not effectively use their resources in production.

Citation: Kakhobwe B., Mangisoni JH., Edriss AK, Kwapata MB and Phombeya H (2009). Technical efficiency of relay cropping agroforestry technology: a case of Zomba district in Malawi, *Technical efficiency of relay cropping agroforestry* 4, pp. 1-7

8.28 Assessing the competitiveness of agroforestry technologies in Ntcheu rural development Project in central Malawi

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The study used a polity analysis matrix (PAM) to analyse how agroforestry based-technologies compete among themselves with regard to maize production on smallholder farms in Ntcheu Rural Development Project. The projects studied were Tephrosia vogelii and vetiver grass (TV); Tephrosia vogelii, Vetiver grass, Faidherbia albida and Gliricidia sepium (TVFG); Tephrosia vogelii, Vetiver grass and Faidherbia albida (TVF); and Tephrosia vogelii, vetiver grass and Gliricidia sepium (TVG). Data for this analysis was collected; using a structured questionnaire, from 160 stratified randomly sampled households at Njolomole Extension Planning Area in the RDP and from secondary sources such as the Strategic Food Reserve Agency. Results from the PAM model revealed that the agroforestry technologies were facing the negative incentives, the farmers were facing the positive to buy tradable inputs; and the combined effects of transfers and tradable inputs were reducing the private profitability of TVFG and TVG. These results were valued using sensitive analysis which reinforced the superiority of TV and TVF. Thus, although other studies have broadly concluded that agroforestry is socially and financially profitable, such conclusions are only valid with specific to tree-crop interactions. To gain greater efficiency in maize production under agroforestry, TV and TVF technologies should be promoted among farmers.

Citation: Longwe A L and Mangison J.H, (2004). Assessing the competitiveness of agroforestry technologies in Ntcheu rural development Project in central Malawi, *Bunda Journal of Agriculture, Environmental Science and Technology* 2, pp. 23-30

8.29 An empirical analysis of smallholder farmer participation in soil erosion control initiatives in Blantyre Shire Highlands of Southern Malawi: a tale of inappropriate interventions

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A probit model and participatory research approach (PRA) methods were used to study factors influencing smallholder farmers in soil erosion control initiatives in Blantyre Shire Highlands of Southern Malawi. A total of 54 adopters and 396 non-adopters were sampled from Chipande, Mbulumbuzi and Mombezi Extension Planning Areas using a combination of stratified random sampling and proportional approaches. The results showed that the most important perception variables in adoption of soil erosion control technologies are effectiveness of the technology, labor requirement, productivity, soil retention and shorted period to accrual of benefits. For non-perception variables, the study showed that land slope, farmer experience and formal and informal education were significant in influencing adoption. The study therefore recommends that any technologies with proven effectiveness should be introduced to farmers. Such introduction should be backed up by a strong formal education and informal education program and appropriate incentives such as prizes and annual festivities organized for successful adopters.

Citation: Mangison JH (2004). An empirical analysis of smallholder farmer participation in soil erosion control initiatives in Blantyre Shire Highlands of Southern Malawi: a tale of inappropriate interventions, *Bunda Journal*

of Agriculture, Environmental Science and Technology 2, pp. 37-47

8.30 Above -and below ground performance of gliricidia sepium/ maize mixed cropping in Makoka, Malawi for 2000/2001 cropping season

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Attempts to overcome the constraints of simultaneous intercropping of nitrogen fixing trees and arable crops have led to a productive investigation, essentially a variant of hedge row intercropping, involving the mixed intercropping of *Gliricidia sepium* with maize. This study assesses the above- and below-ground performance of maize *Gliricidia sepium* system in Makoka, after nine years of continuous cropping. The experiment consisted of two maize treatments with and without *Gliricidia sepium*, and three rates of inorganic fertilizers (0, 23 and 46 kg/ha). The treatments were combined in a factorial design. Our experimental evidence suggests that mixed intercropping is viable and productive. The trees maintained high level of leafy biomass in the 2000/01 season (4.3 t/ha) and still coppiced well, even after nine years of intensive pruning. *Gliricidia sepium* alone increased maize grain yield by 68% compared to the highest inorganic nitrogen rate and about five times as much as the yield in the unfertilized control plots (continuous sole maize cropping). *Gliricidia sepium* prunings alone were not statistically different, compared to the combined effect of *gliricidia sepium* prunings and the highest inorganic nitrogen rate. Continuous application of *Gliricidia sepium* pruning increased the topsoil content of inorganic nitrogen, phosphorus and potassium but slightly decreased the deep subsoil content of these three nutrients. About 80% of maize roots were concentrated to the surface soil (0-40 cm) where as less than 10 % of the *Gliricidia* roots explored the same soil layer, thus minimizing competition between the species. *Gliricidia sepium* mixed cropping is therefore highly promising for rural farmers in southern Malawi, especially given the poor availability of and prohibitive cost of inorganic fertilizer. Once established, *Gliricidia sepium* mixed cropping, when properly managed, could serve as a fertilizer factory on farm.

Citation: Makumba W, Akinnifesi F.K and Kwesiga F.R, (2001). Above -and below ground performance of *gliricidia sepium*/ maize mixed cropping in Makoka, Malawi for 2000/2001 cropping season, Technical Report: World Agroforestry Center, Chitedze Agricultural Station,

8.31 Use of pruning and mineral fertilizer in a gliricidia/maize intercropping system: 2. Phosphorus adsorption and subsequent uptake by maize crop

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Gliricidia sepium-maize intercropping has shown to be a suitable option for soil nutrient replenishment for the sustainable crop production in the southern Malawi. This study was carried out to understand the effect of green manure on phosphorus sorption and subsequent crop uptake under *G. sepium* intercropping. The experiment consisted of two cropping practices (maize with and without *Gliricidia sepium*), three rates of inorganic N fertilizers (0, 46 and 92 kg N/ha) and inorganic P fertilizers (0, 20 and 40 kg P₂O₅/ha) combined in a factorial. Application of *gliricidia* prunings and P fertilizers reduced the P sorption capacity of the soil and the maize P uptake. Langmuir P affinity constant and the Freundlich P adsorption constant were significantly reduced with application of *gliricidia* prunings and inorganic P fertilizer. Combination of *gliricidia* prunings and P fertilizers further reduced the P sorption capacity of the soil compared to the *gliricidia sepium* prunings alone. The results indicate the addition of the *gliricidia* prunings increase P availability in the soil through reduced P sorption capacity of the soil and recycling of P. Combination of *gliricidia* prunings and inorganic P fertilizer has an added benefit compared to application of either *gliricidia* prunings or inorganic P fertilizer alone.

Citation: Mweta DE, Akinnifesi FK, Saka JDK, Makumba W and Chokotho N, (undated), Use of pruning and mineral fertilizer in a *gliricidia*/maize intercropping system: 2. Phosphorus adsorption and subsequent uptake by maize crop, Technical Report, World Agroforestry Center, Chitedze Agricultural Research Station

8.32 Maize and biomass production, and soil fertility improvement under sesbania sesban improved fallows in Kasungu district, central Malawi

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Above ground biomass production and its effects on soil fertility and crop yields was investigated in pure stands of a two-year *Sesbania sesban* improved fallow under smallholder farmer conditions of Kasungu district, central Malawi. The objective of the study was to evaluate soil fertility improvement of improved fallows of improved fallows of *Sesbania sesban* under smallholder farmers' fields that are characterized by poor soil fertility owing to serious land degradation problems. There were four treatments (technologies); T1: growing maize without mineral fertilizer application, (ii) T2: growing maize with mineral fertilizer N and P application (90 kg N/ha and 42 kg P₂O₅ /ha), T3: growing maize in a two year improved fallow of *Sesbania sesban* without mineral fertilizer application, and (iv) T4: growing of maize with mineral N fertilizer application (42 kg N/ha). These treatments were laid out in a randomized complete block design (RCBD) on twenty smallholder farmers's fields each of which was a replicate. Above-ground tree biomass was directly correlated with tree diameter, with coefficient of determinant (R²) of 81 and 82% for leaf and wood biomass, respectively. Both location and gender had no effect on litter accumulation. Ground litter averaged 3.2±0.12 t/ha/year. There were no significant differences (p<0.05) in soil nutrient content across the site and cropping systems, except organic N. The *S. sesban* improved fallow plots yielded significantly (P<0.05) more maize grain and stover yields than unfertilized maize (control) plots. When supplemented with inorganic fertilizer, the *S. sesban* improved fallow yielded the same as growing maize with mineral fertilizer N and P. The amount of accumulated litter was significantly (P<0.001) correlated with maize grain yields. This study has clearly shown the great potential of improved fallows in increasing soil fertility, hence maize yields, under smallholder farm conditions characterized leached and degraded sandy soils.

Citation: Haule CA, Kanyama-Phiri GY, Nyirenda MM, Mafongoya PL and Kwapata MB (2003). Maize and biomass production, and soil fertility improvement under *sesbania sesban* improved fallows in Kasungu district, central Malawi, *Malawi Journal of Agricultural Science* 2(1), pp. 21-33



Part 9: Legumes-Cereal Rotation/Intercropping

9.1 Long-term impact of a gliricidia-maize intercropping system on carbon sequestration in southern Malawi

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Tree/crop systems under agroforestry practice are capable of sequestering carbon (C) in the standing biomass and soil. Although studies have been conducted to understand soil organic C increases in some agroforestry technologies, little is known about C sequestered in simultaneous tree/crop intercropping systems. The main objective of this study was to determine the effect of agroforestry practice on C sequestration and CO₂-C efflux in a gliricidia-maize intercropping system. The experiment was conducted at an experimental site located at the Makoka Agricultural Research Station, in Malawi. The studies involved two field plots, 7-year (MZ21) and 10-year (MZ12), two production systems (sole-maize and gliricidia-maize simultaneous intercropping systems). A 7-year-old grass fallow (Grass-F) was also included. Gliricidia prunings were incorporated at each time of tree pruning in the gliricidia-maize. The amount of organic C recycled varied from 0.8 to 4.8 Mg C ha⁻¹ in gliricidia-maize and from 0.4 to 1.0 Mg C ha⁻¹ in sole-maize. In sole-maize, net decreases of soil carbon of 6 Mg C ha⁻¹ at MZ12 and 7 Mg C ha⁻¹ at MZ21 in the topsoil (0–20 cm) relative to the initial soil C were observed. After 10 years of continuous application of tree prunings, C was sequestered in the topsoil (0–20 cm) in gliricidia-maize was 1.6 times more than in sole-maize. A total of 123–149 Mg C ha⁻¹ were sequestered in the soil (0–200 cm depth), through root turnover and pruning application in the gliricidia-maize system. Carbon dioxide evolution varied from 10 to 28 kg ha⁻¹ day⁻¹ in sole-maize and 23 to 83 kg ha⁻¹ day⁻¹ in gliricidia-maize. We concluded that gliricidia-maize intercropping system could sequester more C in the soil than sole-maize.

Citation: Makumba W, Akinnifesi FK, Janssen B, Oenema O (2007). Long-term impact of a gliricidia-maize intercropping system on carbon sequestration in southern Malawi, *Agriculture, Ecosystems and Environment* 118, 237–243

9.2 The long-term effects of a gliricidia–maize intercropping system in Southern Malawi, on gliricidia and maize yields, and soil properties

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A gliricidia–maize (*Gliricidia sepium* (Jacq.-Zea mays L.) simultaneous intercropping agroforestry system has shown to be a suitable option for soil fertility improvement and yield increase in highly populated areas of sub-Saharan Africa where landholding sizes are very small and inorganic fertilizer use is very low. An 11 year old field experiment, gliricidia–maize simultaneous intercropping, with and without a small application of inorganic fertilizer was studied to increase our understanding of the long-term effects of continuous applications of gliricidia prunings on maize yield and soil chemical properties. The main objectives were to assess: (1) the yield of gliricidia prunings under intensive pruning management, (2) the effect of continuous applications of gliricidia prunings and fertilizer on maize yield and soil properties. During 11 years of intensive pruning, gliricidia trees maintained high levels of leafy biomass production (4–5 Mg DM ha⁻¹). Application of gliricidia prunings increased maize yield three-fold over sole maize cropping without any soil amendments (3.8 and 1.1 Mg ha⁻¹, respectively). Maize yield declined with time under sole maize cropping system in both treatments with and without inorganic N fertilizer. Application of inorganic fertilizer (46 kg N ha⁻¹) in agroforestry systems increased maize yield by 29% (P = 0.002). Application of inorganic P did not significantly increase maize yield implying that the native P in the topsoil and P recycled through gliricidia prunings application was enough to support maize growth. The trees took up “native” soil nutrients (P, Ca, Mg and K) from the depth and pumped these to the surface soil. A net soil nutrient decrease in the gliricidia–maize simultaneous intercropping system was observed due to increased nutrient export.

Citation: Makumba W, Akinnifesi F.K, Janssen B, Oenema O, Kwesiga F and Mweta D, (2006). The long-term effects of a gliricidia–maize intercropping system in Southern Malawi, on gliricidia and maize yields, and soil properties, *Agriculture, Ecosystems and Environment* 116, pp.85–92

9.3 Impact of *Gliricidia sepium* intercropping on soil organic matter fractions in a maize-based cropping system

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The gliricidia (*Gliricidia sepium*) /maize intercropping system holds promise for increasing productivity in maize-based cropping systems on depleted soils in Southern Africa. The effect of the intercrop on soil properties was investigated to better understand soil processes underlying maize yield response, soil nutrient recapitalization and soil carbon sequestration. Soil organic matter (SOM) fractions, particulate organic matter (POM), POM-carbon, POM-nitrogen, soil nutrient status and underlying soil characteristics were quantified on the 14th year of a gliricidia/maize intercrop establish in 1991 on a Ferric Lixisol in southern Malawi. A factorial design compared the intercrop and a sole maize crop at three rates of added inorganic nitrogen (N) and phosphorus (P). Gliricidia leaf biomass was incorporated into the maize three times per year. Soil was sampled to a 20 cm depth, post-harvest to analyze biophysical and chemical characteristics of soil organic matter, POM, POM-C and POM-N, as well as inorganic N, available P, exchangeable K⁺ and particle size distribution. The gliricidia/maize intercrop had a significant and positive effect on SOM, POM, and SOM fractions: SOM was 12% higher, POM 40%, POM-C 62%, and POM-N 86% higher in the gliricidia intercrop compared to sole maize, indicating nitrogen enrichment of POM. Nitrogen fertilizer was associated with modest increases in POM, 15% in gliricidia and 27% in sole maize. The impacts of these changes were directed mostly at increasing maize yields and increasing storage of soil nutrients over the short term, while decreasing the proportion of organic matter stored over the long term. Both the gliricidia/maize intercrop and increasing soil clay content were associated with significantly increased soil CEC. The gliricidia intercrop maintained CEC in coarse-textured soils over a 14-year time span, indicating a role for legume trees in intensified cropping of coarse-textured soils.

Citation: Beedy TL, Snapp SS, Akinnifesi FK, Sileshi GW (2006). Impact of *Gliricidia sepium* intercropping on soil organic matter fractions in a maize-based cropping system, *Agriculture, Ecosystems and Environment* 138, pp. 139–146

9.4 Mixed-species legume fallows affect faunal abundance and richness and N cycling compared to single species in maize-fallow rotation

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Rotation of nitrogen-fixing woody legumes with maize has been widely promoted to reduce the loss of soil organic matter and decline in soil biological fertility in maize cropping systems in Africa. The objective of this study was to determine the effect of maize-fallow rotations with pure stands, two species legume mixtures and mixed vegetation fallows on the richness and abundance of soil macrofauna and mineral nitrogen (N) dynamics. Pure stands of sesbania (*Sesbania sesban*), pigeon pea (*Cajanus cajan*), tephrosia (*Tephrosia vogelii*), 1:1 mixtures of sesbania and pigeon pea and sesbania and Tephrosia, and a mixed vegetation fallow were compared with a continuously cropped monoculture maize receiving the recommended fertilizer rate, which was used as the control. The legume mixtures did not differ from the respective pure stands in leaf, litter and recycled biomass, soil Ca, Mg and K. Sesbania and pigeon pea mixtures consistently increased richness in soil macrofauna, and abundance of earthworms and millipedes compared with the maize monoculture (control). The nitrate-N, ammonium-N and total mineral N concentration of the till layer soil (upper 20 cm) of pure stands and mixed-species legume plots were comparable with the control plots. Sesbania and pigeon pea mixtures also gave higher maize grain yield compared with the pure stands of legume species and mixed vegetation fallows. It is concluded that maize-legume rotations increase soil macrofaunal richness and abundance compared with continuously cropped maize, and that further research is needed to better understand the interaction effect of macrofauna and mixtures of organic resources from legumes on soil microbial communities and nutrient fluxes in such agroecosystems

Citation: Sileshi G, Mafongoya P. L, Chintu R., Akinnifesi F. K, (2008). Mixed-species legume fallows affect faunal abundance and richness and N cycling compared to single species in maize-fallow rotation, *Soil Biology & Biochemistry* 40, pp. 3065–307

9.5 Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in central Malawi

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Using farmer resource typologies, adaptability analysis and an on-farm mother and baby trial approach, we evaluated the production risks of alternative maize-legume crop combinations for smallholder farmers in Chisepo, central Malawi between 1998 and 2002. Production benefits and risks of four soil fertility and food legumes, pigeonpea (*Cajanus cajan*), groundnut (*Arachis hypogaea*), tephrosia (*Tephrosia vogelii*) and mucuna (*Mucuna pruriens*), intercropped or rotated with maize, were compared by 32 farmers in 4 farmer resource groups (RGs) of different wealth status. The calculation of lower confidence limits was used to determine the production risk of the crops. Alternative crop technologies presented different risks to farmers of different wealth status, and the degree of risk affected their choice of soil fertility management strategy. The better resourced farmers (RG 1) had larger yields with all crop combinations than the poorly resourced farmers (RG 4). Legumes integrated with maize significantly ($p < 0.001$) raised maize grain yields by between 0.5 t ha⁻¹ and 3.4 t ha⁻¹, when compared with sole crop unfertilized maize. Fertilized maize was less of a risk for the better-resourced farmers (RG 1 and RG 2), and it yielded well when combined with the legumes. Maize-legume intercrops yielded more and were associated with less risk than the maize-legume rotations. Maize intercropped with pigeonpea was predicted overall to be the least risky technology for all RGs. We conclude that new crop technologies may pose more risk to poorly resourced farmers than to wealthier farmers

Citation: Kamanga BCG, Waddington SR, Robertson MJ and Giller KE (2010). Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in central Malawi, *Expl Agric.* 46 (1): 1–21.

9.6 Spatial rooting patterns of gliricidia, pigeon pea and maize intercrops and effect on profile soil N and P distribution in southern Malawi

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The concept of competition or complementarity between tree and crop roots for below ground resources have been a major debate in simultaneous systems. Root studies were conducted in three cropping systems, namely: sole maize, pigeon pea/maize intercropping and Gliricidia sepium (Gliricidia)/maize intercropping, with the objective of understanding the potential for competition or otherwise. Pigeon pea and maize root development was monitored at 21, 42 and 63 days after planting (DAP). Also soil mineral N and Olsen P were assessed along the soil profile up to 200 cm depth. Maize roots developed faster than those of pigeon pea during the first 42 days after planting and there was little overlapping of maize and pigeon pea roots. However, the roots of both pigeon pea and maize had its peaks at 63 DAP, suggesting potential competition during reproductive growth stage of maize. In Gliricidia/maize intercropping, maize had the highest root density averaging 1.02 cm cm⁻³ in the top 0 - 40 cm soil layer, whereas gliricidia had lower root length density (0.38 cm cm⁻³) in the top 0 - 40 cm soil layer compared to 0.65 cm cm⁻³ in the subsoil (40 - 100 cm). In Gliricidia/maize intercropping, mineral N was increased by 34 - 44 kg ha⁻¹ in the 0 - 100 cm soil layer, whereas Olsen P decreased by 32 kg ha⁻¹ in the entire 0-200 cm soil profile compared to the sole maize plot. Pigeon pea may be the "loser" in an association that involved both maize and Gliricidia. Because maize had more roots growing within 0 - 40 cm soil layer than Gliricidia it is able to take advantage of the nutrients from the applied Gliricidia prunings in the ridges. The study confirmed root compatibility between Gliricidia and maize and nutrient pumping from deep soil layers.

Citation: Makumba W, Akinnifesi F. K and Janssen B. H, (2009). Spatial rooting patterns of gliricidia, pigeon pea and maize intercrops and effect on profile soil N and P distribution in southern Malawi, *African Journal of Agricultural Research* Vol. 4 (4), pp. 278-288

9.7 Role of cowpea and silverleaf in intercropping of witchweed (*Striga asiatica* (L.) Kuntze) in maize in Malawi

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The parasitic witchweed (*Striga asiatica* (L.) Kuntze) is a major constraint to maize production in Malawi. Intercropping maize with some legumes is one way to suppress its emergence. A trial was therefore conducted in 2000/01 and '01/02 seasons to determine the effect of intercropping maize with cowpea or the silverleaf intercropping population and pattern for maize at 90 cm between rows and 75 cm between hills, 3 seeds per station. In 2000/01 season, maize yields were reduced from 1900kg/ha in pure maize to 1300kg/ha by planting 2 hills of cowpeas, two seeds per hill in between maize stations (59 000 cowpea plants per hectare (treatment three)). In the second season maize yields were unaffected (mean 4247kg/ha). In all seasons cowpea yields were maximized with same treatment three. In the first season witchweed emergence in treatment three was 10 plants m⁻², compared to 35 plants m⁻² in pure maize. In the second season emergence was 1.5 plants m⁻², compared to 11.2 plants m⁻² in pure maize. Silverleaf did not germinate in the first season; hence evaluation was done in second season only. Drilling silverleaf at the time of planting gave significant reduction of number of *Striga* capsules m⁻². The results confirm that cowpea intercropping suppresses witchweed, but that under a low potential environment, yields of maize might be suppressed.

Citation: Kabambe VH, Nambuzi S, Kauwa AE and Ngwira AR (2005). Role of cowpea and silverleaf in intercropping of witchweed (*Striga asiatica* (L.) Kuntze) in maize in Malawi, In: Safalaoh ACL, Gowela JP and Mtethiwa AHN, editors. Proceedings of the 2nd Bunda College research dissemination conference, Bunda College of Agriculture, Lilongwe. pp. 22-27

9.8 Integrated management of witchweed (*Striga asiatica* (L.) Kuntze) by means of maize legume rotations and intercropping systems in Malawi

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A four year study was conducted at Mponela in Dowa district, Central Malawi, from 1997/98 to '00/01 season to evaluate the role of one year rotation of velvet beans (*Mucuna pruriens*) and groundnuts (*Arachis hypogaea* L.), pigeon peas (*Cajanus cajan*) intercropping and tephrosia (*Tephrosia vogelii*) undersowing and fertilizer application (69:21:0+4S) on witchweed (*Striga asiatica* L. Kuntze) suppression and associated grain yield. Initial maize grain yield were low, averaging 0.19 t/ha for unfertilized and 1.28t/ha for fertilized. There were no significant ($P>0.05$) treatment differences in *Striga* emergence in the first two seasons, averaging $f<4$ plants m⁻². In the third and fourth season, significant ($P<0.05$) differences in the *Striga* emergence were observed. *Striga* peaked at less than 3 and 5 plants m⁻² in maize after groundnuts or mucuna and continuously fertilized plots, compared to 19 and 32 plants m⁻² in continuous unfertilized maize, respectively. In the fourth (final) season, yields for fertilized maize were 1.45 t/ha. Yields for maize after legume rotations were significantly higher than unfertilized maize only with mucuna rotation and in the second season only. Highest amount of estimated dry matter yield of legume stover was 0.9t/ha for groundnuts, 3.4t/ha for mucuna and 1.6 t/ha for tephrosia. The suppression effect of legume systems on *Striga* are therefore more pronounced with time, while in uncontrolled plots rapid build-up occurs. Although positive effects of mucuna rotations on soil fertility enhancement and *Striga* suppression were evident, an integrated approach is suggested to complement these observed results.

Citation: Kabambe VH, Nambuzi SC and Kauwa AE (2008) Integrated management of witchweed (*Striga asiatica* (L.) Kuntze) by means of maize legume rotations and intercropping systems in Malawi, Bunda Journal of Agriculture, Environmental Science and Technology 3: 35-42.

9.9 Management of alley cropping with maize (*Zea mays* L.) and *Leuceana leucocephala* (Lam) de Wit in Malawi

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Information in this paper is intended to serve as a practical guide for alley cropping with *Leucaena* and maize in Malawi. It is based on several seasons of research by Agroforestry Commodity Team at Chitedze Agricultural Research Station. Important management issues are highlighted and discussed including *Leucaena* seed treatment. Nursery management, hedgerow establishment and spacing, pruning practices, and the timing and method of applying leaf manure.

Data from several long term trials are used to demonstrate the effect of *Leucaena* leaf pruning on maize yields with and without supplementary fertilizer. The benefits and limitations of alley cropping with *leucaena* are also discussed in relation to potential farmer adoption.

Citation: Bunderson T W, Saka A.R, A Itimu O, Mbekeani Y, and Phombeya H.S.K, (undated), Management of alley cropping with maize (*Zea mays* L.) and *Leucaena leucocephala* (lam) de wit in Malawi, A paper presented at National Agroforestry Symposium, Agroforestry Commodity Team, Chitedze Agricultural Research Station



Part 10: Tillage, Irrigation and Other Agronomic Practices

10.1 Development of agronomic cultural practices for winter maize production along dambos and valleys

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Although production of maize under residual moisture is common along dambos and the valleys by utilizing the residual moisture, the technologies for producing maize under this system are limited. Research was initiated in 1995/96 season to generate technologies for winter maize production in Karonga, Mzuzu, Salima and Shire Valley Agricultural Development Divisions (ADDs). Three experiments were conducted for three winter seasons to evaluate the performance of different maize varieties under winter maize production, to determine the effect of nitrogen application and to determine the response of maize to different planting time and densities. Hybrid maize PAN 6193 (Kaswiri) outyielded all the maize varieties at all location in 1998 and this trend was observed for all the three previous seasons across 15 sites. The order was for hybrids to outyield synthetic and local being the least yielding. Again PAN 6193 had the greatest tolerance to Maize Streak Virus Disease. Nitrogen application increased maize yields at all locations by around 25% across seasons and years. Planting at the end of the rainy season (June) gave highest yield. However, for cooler areas planting towards the end of June gives a better yield. There were no differences in maize yield by increasing maize density from 37 000 plants to 62000 plants per hectare between 1995 and 1997 and mulching did not affect the maize yield across seasons.

Citation: Sakala W.D, Kumwenda, J.D T and Kamalongo D, (1996), Development of agronomic cultural practices for winter maize production along dambos and valleys, Technical report, Chitedze Agricultural Research Station, Lilongwe, Malawi

10.2 Effect of reduced tillage on nutrient use efficiency for 1996/97 cropping season

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A study was carried out to develop minimum/ reduced tillage crop production practices with some slight dose of inorganic fertilizers for improved maize production under smallholder farm conditions in Malawi. The study commenced in 1996/97 and was sited at Chitedze and Bvumbwe Agricultural Research Station. The experiment comprised of two factorial combination of two factors; tillage system and nitrogen levels. The experimental soil at Chitedze site is an Alfiso that has a minimum content of organic matter and nitrogen. Other nutrients elements (P, K, Ca and Mg), are low to medium with a medium textured top soil (SCL). The soil at Bvumbwe is Ferruginous Latosol that is predominately sandy clay loams in texture and strongly acidic in reaction (pH 4.4-5.0). The soil organic matter and nitrogen content are medium (1.52-4.5% and 0.09-1.15%, respectively. Phosphorus is very high (>34ppm); potassium and magnesium are high, calcium is medium (0.50-0.80, 0.6-3.0 and 5.0-10.0 Cmol/kg soil, respectively). The study has shown that there is a linear relationship between yield and additional dose of inorganic fertilizer. However, economic yield is attained under a reduced tillage system at about 23 kg/ha of inorganic nitrogen.

Citation: Chigowo M.T (1997), Effect of reduced tillage on nutrient use efficiency, Technical Report, Blantyre Agricultural Development Division, Land Resources Conservation Department, Blantyre, Malawi

10.3 Effect of reduced/minimum tillage on soil and water management for maize production in Malawi for 1996/97 cropping season

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A study was carried out to develop minimum/reduced tillage crop production practices for improved maize production under smallholder farm conditions in Malawi. The study commenced in 1996/97 with the aim of producing biomass for incorporation into the experimental treatments of the crop season. Spatially the study was replicated in three sites; Chitedze, Chitala and Mbawa. The experiment comprised of a factorial combination of three factors; depth of tillage, seedbed preparation technique and crop residue management practices. The experimental soil at Chitedze and Chitala is an Alfisol that has a medium content of organic matter and nitrogen. Other nutrients elements (P, K, Ca and Mg), are low to medium with a medium textured top soil (SCL).

The soil at Mbawa is an Ultisol that has low to medium contents of organic matter and nitrogen. Other nutrient elements (P, K, Ca and Mg) are low to very low with a fine textured top soil (SCL/SC). The differences in soil nutrient build up within treatments are not statistically significant at 5% level of probability. However, there was an increase in organic matter and available nitrogen in the minimum tillage treatments. A similar trend was also observed in the minor elements. Soil physical parameters did not significantly change within the treatments as compared to the initial soil. The effects of termite damage to the crop were not significantly different within the treatments although, less damage was observed where crop residues were left on the surface. There was sufficient soil water during the seasons as such methods of land preparation did not show any significant differences in the soil water conservation. The two years of study, minimum tillage with residues removed from the surface (treatment 10), outyielded the rest of other treatments at Chitedze and Chitala, whilst at Mbawa, this treatment tarried with the conventionally tilled plot with residues left on the surface and planted on the flat (treatment 4). Significant differences within treatments in yield were observed during the first year at Chitedze and second year at Chitala at 5 % level of probability.

Citation: Chigowo M.T and Saka A.R (1997). Effect of reduced/minimum tillage on soil and water management for maize production in Malawi for 1996/97 cropping season, Technical Report, Blantyre Agricultural Development Division, Land Resources Conservation Department, Blantyre, Malawi

10.4 The potential of improved fallows on smallholder maize productivity and food security in Malawi

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Using preliminary biomass and maize yield results of improved fallows in Malawi, a linear programming model was constructed to evaluate potential adoption of this technology, and its impact on food security at the household and national levels over a twenty year time period. The model demonstrates the use of a flexible integrated approach for evaluating new technology developments in relation to existing practices and other improved alternatives. Gaps and limitations that demand further research are also identified, focusing on technology testing and adaptation with farmers, before promoting broad based extension efforts. Model results indicate that the standard 2-year fallow has little potential for adoption due to land constraints in Malawi. Farmer adaptations of this practice show more promise. One involves undersowing tree legumes with maize in the first season to reduce the fallow period. Household food security results generated indicate that small farmers will not be able meet minimum nutritional requirements even following adoption without access to off-farm and/or food-for-work opportunities. Additionally, food requirements at the national level cannot be met without reductions in population growth or promoting commercial maize production by the estate sector.

Citation: Hayes IM, Bunderson WT, Minae S, Bodnar F and Ngugi D (undated). The potential of improved fallows on smallholder maize productivity and food security in Malawi, Technical Report, Chitedze Agricultural Research Station, Lilongwe, Malawi

10.5 The impact of land use on soil carbon in Miombo Woodlands of Malawi

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In the Miombo Woodlands Region of south-central Africa, it is estimated 50–80% of the total system's carbon stock is found in the top 1.5 m belowground. Deforestation and rapid population growth rates have led to reduced fallow periods and widespread land degradation in the south-central Africa area of the Miombo Woodlands. The impact of this land use conversion on belowground carbon and nitrogen stocks within the Miombo Woodlands has not been examined extensively in the past. We addressed how the soil carbon profile reacts to conversion to agriculture, the continuation of agriculture, and the ability of the soil carbon budget to recover following abandonment within the Chimaliro Forest Reserve and surrounding villages in Kasungu, Malawi. Protected natural Miombo Woodlands sites, agricultural fields of increasing ages, and fallow fields of increasing ages were sampled. Surface carbon levels in Miombo soils varied from 1.2 to 3.7%. Agricultural soil carbon was significantly depressed with surface layers ranging from 0.35 to 1.2% carbon. Unexpectedly, fallow carbon and nitrogen levels continued to be significantly repressed (surface soils 0.65–2.3% C), pointing out the possible unsustainability of the current agricultural management cycle dominant in the area. On average, agricultural soils contain 40% less soil carbon than the natural Miombo Woodlands. Soil carbon declined logarithmically with depth within all land use types. Clay content was significantly positively correlated with soil carbon in the top 40 cm and therefore areas of higher clay content contained elevated carbon levels. Although a common attribute to many agricultural systems, bulk densities were not significantly altered by land use changes.

Citation: Walker SM and Desanker PV (2004). The impact of land use on soil carbon in Miombo Woodlands of

Malawi, Forest Ecology and Management 203: 345–360

10.6 Investigating local farmers' general knowledge of the effectiveness of the 4Rs in as far as improvement of crop productivity in a sustainable manner is concerned: a case study of two livelihoods zones in Mangochi district

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Soil nutrients influence soil productivity and hence the knowledge of plant nutrient management information and the 4Rs (Right source of soil nutrients, Right rate/quantities of the nutrients, Rite time and Right place) by local farmers can assist them to increase crop yields. This study was conducted in the two livelihoods zones of Mangochi district, the Highland East (Namwera Plain (and the Highlands West (Chilipa Plain) to investigate the general knowledge of the plant nutrient management and the effectiveness on the 4Rs. The two zones have similar soil type, weather and topography. From time in memorial, these areas have been rich agricultural areas, however, during the past six years or so crop production from these areas have been diminishing with visible signs of decreasing soil fertility status. The study involved Focus Group Discussion, In-depth Interviews and literature review. The respondents were the key informants and knowledgeable individuals conversant with soil fertility management. The results have revealed that there is severe lack of knowledge of the 4Rs which in turn is affecting crop productivity. Because of issues of culture, mindset of and production orientation, many smallholder farmers don't associate diminishing crop production to decreasing soil fertility status.

Citation: Mahwayo D.P and Jalasi B (undated). Investigating local farmers' general knowledge of the effectiveness of the 4Rs in as far as improvement of crop productivity in a sustainable manner is concerned: a case study of two livelihoods zones in Mangochi district, Technical report, Given-Secret Foundation, Mangochi, Malawi

10.7 Soil penetration resistance, root growth and yield of maize as influenced by tillage systems on ridges in Malawi

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Ridge-tillage is a traditional method of seedbed preparation in Malawi and it is performed annually by manual operation with a hand hoe. A 3 year experiment was conducted to evaluate the effect of minimum (MT) and conventional (CT) ridge tillage systems on soil strength and maize (*Zea mays*) growth. Minimum tillage consisted of planting maize on ridges made in the previous year(s) while in CT it was grown on new ridges constructed at the beginning of each season the soil an Oxic Rhodustalf. Results indicated that a distinct hard and compact layer had developed below the ridges (about 25 cm depth) in CT and MT. Soil on ridges of CT had consistently lower penetration resistance of soil on the ridges were less under CT than under MT. Penetration resistance of the soil on both tillage treatments was strongly related to soil water content, which depended on the amount of rainfall. Consequently, the pattern in changes of penetration resistance in the soil during the season generally mirrored that of rainfall. The presence of compacted subsurface soil layers in both treatments and the significantly higher ($P \leq 0.05$) penetration resistance in the MT affected root penetration and distribution. The MT had significantly lower root length density in the 0-20 cm depth and roots were concentrated near the surface compared with those of CT. Maize grain yields, however, were not affected by the tillage system in the first two seasons of the study but significantly reduced by MT in the third season. The average grain yield over the three seasons were 4812 and 4644 kg/ha for CT and MT respectively. Use of MT resulted in remarkable reductions of working time and energy requirement for maize production compared with CT. This study has shown that maize yield of around 4000kg/ha can be achieved using previous year ridges under smallholder farmer circumstances of low resource inputs.

Citation: Materechera S.A and Mloza-Banda H.R, (1997). Soil penetration resistance, root growth and yield of maize as influenced by tillage systems on ridges in Malawi, Soil and Tillage Research 41, pp. 13 -24

10.8 Assessment of tie ridging on smallholder maize yields in Malawi

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Tie-ridging is being promoted in Malawi as an on-field rainfall harvesting technique to ensure maize (*Zea mays* L) during a dry or drought year. Resource poor smallholder farmers are likely to take up tie-ridging if it increases and decreases maize yield in most years. A numerical study was conducted to calculate the expected maize yield gain due to tie ridging taking into account the probability of occurrence of drought, dry, normal and wet years (climate

uncertainty). Mean yields due to tie ridging in drought, dry, normal and wet years at different an levels were dried from observed smallholder maize yield data using a linear nitrogen response model and field-observed retained rainfall amounts in tie-ridged fields. Simulation results indicate that tie ridging will result in hybrid maize gain in the drought (1050 kg/ha⁰ and dry year (560 kg/ha). There will be a hybrid maize loss in a normal year (350 kg/ha) and wet year (700 kg/ha), dry year (220 kg/ha) and normal year (120 kg/ha). There will be a slight yield loss in a wet year (60kg/ha). Considering observed probability of occurrence of drought, dry, normal and wet years in Malawi. The study reveals that there will not be hybrid maize yield gain in any coming year with tie ridging. For local maize, the expected yield gain in any coming year was positive (133.3 kg/ha) but this gain is less than the minimum gain required considering the opportunity cost of labour (142.5 kg/ha). Thus under the smallholder and climate of Malawi, the expected yield gain in any coming year due to tie-ridging is likely to be minimal and uneconomic.

Citation: Wiyo KA and Feyen J (1999). Assessment of tie ridging on smallholder maize yields in Malawi, *Agricultural Water Development* 41: 21-39

10.9 Modeling and participatory farmer-led approaches to food security in a changing world: A case study from Malawi

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Crop diversification has a long history in Africa, as a foundation for more resilient and sustainable farming systems. However, success has often been mixed. Variable weather and changing climate requires a focus on supporting farmer capacity to adapt and innovate. Participatory research and simulation modeling are uniquely suited to this goal. Here we present a case study from Northern Malawi where crop modeling in conjunction with participatory approaches were used to evaluate the performance of the promising mixed cropping systems, involving maize and pigeon pea. Using historical rainfall records, simulated yield (Agricultural Production Systems Simulator, APSIM) from maize and pigeon pea-maize intercrop and rotation systems was compared to food requirements for 12 households selected to represent a range of wealth status. We found that pigeon pea-maize intercrops were highly likely to produce sufficient calories for smallholder households across variable rainfall patterns, from 73 to 100% of the years simulated, for 10 out of 12 case study households. This stands in contrast to monoculture maize, where sufficient calories were consistently produced for only half of the case study households. Survey data from this case study documented adoption patterns that reflected strong interest in legume mixtures, and gains in farmer capacity. Farmers shared agronomic information and seeds of pigeon pea and other improved legumes. Overall, we found that farmers were highly motivated to experiment with and adopt legumes that produced food and other valued combinations of traits, whereas green manures met with limited interest. Notably, farmers prioritized species that were reliable at producing food under variable rainfall. Support for farmer-to-farmer learning was critical to the success of the project, and a co-learning approach provided valuable insights to researchers regarding which technologies were more adaptable, and ultimately, adoptable by smallholders living in a highly variable environment.

Citation: Snapp SS, Kerr RB, Smith A, Ollenburger M, Mhango W, Shumba L, Gondwe T and Kanyama-Phiri G Y (2013). Modeling and participatory farmer-led approaches to food security in a changing world: A case study from Malawi, *Secheresse* 24, pp. 350-358. doi: 10.1684/sec.2014.0409

10.10 The effect of maize intercropping system on the growth and reproduction of blackjack (*Bidens pilosa*, L) and the maize cowpea intercropping

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A field experiment was conducted in Zomba, Southern Malawi to assess growth and yield of maize when intercropped with cowpea and to evaluate the effect of intercropping system on growth and reproduction of *Bidens pilosa*. Five maize-cowpea cropping patterns: sole maize, sole cowpea, cv Sudan 1, sole cowpea, cv Local, maize-cowpea cv Sudan 1 and maize-cowpea cv. Local were used in combination with three *Bidens pilosa*

densities at 0, 5 and 10 plants at each maize-cowpea planting hill. Crop yield data showed that maize did not suppress cowpea yield in intercrop treatments but grain yield of maize intercropped with cowpea cv Sudan 1 was 5 per cent higher than that of maize cowpea cv local. Higher *B. pilosa* led to greater reduction in maize and cowpea yield, total land equivalent ratio and gross returns. Intercropping of maize with cowpeas and increasing *B. pilosa* greatly succumbed to both interspecific and intraspecific competition. It is therefore concluded that intercropping, if efficiently utilized, provides a complementary and preventive strategy in weed management by reducing the reproductive fitness of weeds.

Citation: Munthali B.C and Mloza- Banda H.R, (2003). The effect of maize intercropping system on the growth and reproduction of blackjack (*Bidens pilosa*, L) and the maize cowpea intercropping. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 17-26

10.11 The influence of intercropping on labour for weed control in maize based systems in southern Malawi

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Intercropping of maize with cowpea in relation to labor for weed control was assessed in a field experiment in Southern Malawi based on the following treatment effects: maize-cowpea intercrops, sole maize, sole cowpea, two cowpea cultivars, two cowpea spatial arrangement and two weeding regimes. Intercropping significantly ($p=0.0001$) reduced weed density by 62 and 43 percent when the crop was weeded two and six weeks after planting, respectively. Maize-cowpea intercropping reduced the amount of labour at weeding and improved gross margins. Intercrop spatial arrangement did not influence the weeding and total land equivalent ratio for the three seasons of study indicated that the cropping systems affected the two cropping systems differently. Maize-cowpea intercropping resulted in a yield return to labour which was 10- 30 per cent higher than in sole cropping suggesting that labour use efficiency improved by intercropping

Citation: Munthali BC and Mloza- Banda HR (2003). The influence of intercropping on labour for weed control in maize based systems in southern Malawi. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 37-46

10.12 Sustainable utilization of natural, financial and human resources for weed research and technology development in East and Southern Africa

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It is recognized that the prevailing production systems and current available weed control measures are insufficient to contain population of weeds at non-injurious level. In order to ensure that users of land and water in the region realized greater benefits from weed research and technologies, it is essential to build on the past subtle individual successes and wholesomely address emerging challenges. In sub-Saharan Africa, it is estimated that weeds cause great crop losses averaging 30%. In reality though, losses of 59% or more are common especially with weeds such as witchweed in maize, wild rice in rice and sedges, under dambo cultivation. Yet, weeds, remain as underestimated terrestrial and aquatic pests for which government spending on training, research and extension is minimal and appropriate weed management technologies remain largely unavailable and/or undeveloped. This paper notes that weed control is the best user of inputs. The high labour demand, especially in smallholder agriculture, is of social concern. Small scale farmers spend more than 40% of their labour time in weeding. This is mainly female and child labour from the farmers' family. The paper calls for weed control innovations aimed at making manual and cultural weed control methods more efficient. Indeed, over the decades, the phenomenon of migration from the town or to employment to plantations elsewhere, and the slashing intrusion of HIV/AIDS have noticeably changed the population structure of the village. The removal of up to 20% and more of the 'productive' group in the community is as deadly for the future as it is for the present. This paper calls for technologies that consider the position and needs of the present communities in the types and shapes of the tools they can use for working to ensure productive use of resources with diminution of the weed problem. A preventative for optimal development of a sound management programme is training and specialization of the national technical staff that include non-governmental organizations. The paper recognizes the need of action that demonstrates weed research and training as playing a leading role since this discipline has not only the task to protect aquatic and agro ecosystems from losses due to weeds, but also the task to develop methods permitting reasonable engagement of manpower resources, decrease energy input to a minimum, and source productivity of land and water resources.

Citation: Malindi ES and Mloza-Banda HR (2003). Sustainable utilization of natural, financial and human resources for weed research and technology development in East and Southern Africa. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 1-4.

10.13 Evaluation and development of late and intermediate maize varieties for tolerance/ resistance to *Striga asiatica* in Malawi

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In 1998/99 season a program was initiated at Chitedze Research Station, Lilongwe, Malawi to evaluate various parasitic weed, *Striga asiatica* (witchweed). Twelve late to intermediate open pollinated varieties (OPVs), originating from International Institute of Tropical Agriculture (IITA), including a local check, Masika, were evaluated under artificial inoculation. Results showed there were significant ($p=0.05$) variety effect on grain yield, field stover weight and *Striga* counts at 66 and 92 days after planting (DAP) three entries; STR.EV.IWF, and IWFSTR.CO, and Masika yielded over 6.0 t/ha. The lowest *striga* emergence at 92 DAP was 20.8 plants/m² on the entry TZL Comp. 1 C4. However, this entry yielded over 6.0 t/ha lower than Masika's 6.6 t/ha. Varieties were also assessed for grey leaf spot (*Cercospora zeae maydis*), leaf blight (*Helminthosporium turcicum*) and common rust (*Puccinia sorghi*). In the subsequent season, due to concerns on the lower yield potential of IITA entries, some top crop hybrids were made between entries with low support for *Striga* (TZL Comp.C4-W, Z diploBC4C1, and AK94TZEC Comp.5-W) with some of the established inbred lines in the breeding program (Manica-4, MCL 202 and CML 387) to improve yield potential. Analysis of variance results gave significant ($p=0.05$) hybrid and *Striga* infection on the station and hybrid and fertilizer infection on the farm. The hybrids TZL Comp. C4-W x Manica-4 and Z.diploBC41 x CML202 did well, yielding 1.0 to 2.0 t/ha more than local checks MH18 and Masika on station and on farm under moderate fertilizer use (69 kg N /ha or less). The hybrids were however intermediate in *Striga* suppression. It is concluded that maize germplasm with useful partial resistance to *Striga* is available for direct use or improvement. It is suggested that such varieties are best presented as material doing well under range of stresses and responding well to sound integrated control measures.

Citation: Kabambe VH and Ganunga RP (2003). Evaluation and development of late and intermediate maize varieties for tolerance/ resistance to *Striga asiatica* in Malawi. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 97-103

10.14 Control of *Striga asiatica* in maize by means of crop rotation and intercropping in Malawi

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A field trial was conducted for four seasons at Manjawila in Malawi to evaluate the role of trap crops in the integrated management of *S. asiatica* in maize. *Striga asiatica* incidence declined steadily from a maximum of 20 plants /m² in the first season to 4, 0.5 and 3.6 after one, two and three seasons, respectively, of trap cropping with either groundnut or cotton. Intercropping with cowpea gave the least incidence from the first year through the fourth season, when a pure stand of maize was grown to all plots. Soil temperatures in the maize- cowpea intercrop averaged 30.5°C, compared to 35°C in pure maize at flowering. Photosynthetically active and direct (sunfleck) radiation interception in intercrop. Removal of *Striga asiatica* resulted in its reduced incidence in the subsequent seasons. In the fourth season a natural decline in the *Striga asiatica* was evident in the uncontrolled plot, probably due to overall sound management which included use the hybrid, timely planting and fertilizer application and residue incorporation. Maize yields varied with seasons, but generally were higher when it was grown after a trap crop. Phosphorus test values increased from 4.2 to 23 ppm in plots grown to continuous cotton or maize (with fertilizer application), but remained low (4.2 to 5.7 ppm) in continuous groundnuts. Organic matter and nitrogen remained low throughout, averaging 0.05 and 0.94 %, respectively.

Citation: Kabambe VH and Drenman DSH (2003). Control of *Striga asiatica* in maize by means of crop rotation and intercropping in Malawi. In Mloza-Banda H.R and Salanje G.F, editors. Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi: WSSEA, pp. 105-111

Part 11: Dissertation and Thesis

PhD AND MSC RESEARCH

A11.1 Nitrogen budgets in legume based cropping systems in northern Malawi

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Smallholder farmers in sub Saharan Africa (SSA) operate in a risky environment characterized by low soil fertility, unpredictable weather and markets. Identification of technologies that optimize crop yields in a variable climate, while building soil fertility, can contribute to sustainable cropping systems. Participatory on-farm trials were conducted in Ekwendeni of northern Malawi to evaluate performance and yield of legume diversified cropping systems. Prior to implementation of trials, household and farm field surveys were conducted to characterize cropping systems and soils. Soil fertility among farms was highly variable and largely coarse textured with very low organic matter ($12 \pm 3.7 \text{ g kg}^{-1}$). There was no evidence of cropping systems effect on nutrient levels except for inorganic P which was lower in legume diversified fields than in maize fields. A survey showed that farmers valued a wide range of legume traits that included food, yield, maturity period, post harvest handling, soil fertility, market potential and pest resistance. On-farm trials evaluated maize-based cropping with a range of legume growth types and planting arrangements (groundnut representing an annual grain legume and pigeonpea representing a semi-perennial grain legume, planted as sole and intercrop systems rotated with maize). The trials were conducted over two years and showed that interspecific competition, inorganic P and plant density markedly influenced crop growth and biological nitrogen fixation (BNF). The type of species present in the intercrop – legume or cereal - did not alter the BNF response. On area basis, there was no evidence of higher N fixation rate by groundnut-pigeonpea intercrop (GNPP) “doubled-up legumes” compared to sole stands of either species. Overall performance of intercrops vs sole crops was superior in terms of grain yield produced in the first year of the rotation, as indicated by calculation of a land equivalent ratio (LER). The LERs were 1.50 and 1.56 for GNPP and MZPP compared to sole crops, indicating that intercropped species were more efficient at utilizing resources than sole stands. Performance over the two years of the cropping system was evaluated in 2008/2009. Maize was planted on fields previously planted to sole or intercropped legumes. Indicators of N status (chlorophyll and biomass) showed that maize growth in year two was influenced by cropping system. In contrast, soil inorganic N did not show a response to cropping system. A previous crop of sole or intercropped legumes increased maize grain yields by 21-62% compared to a previous crop of maize. Integrated soil fertility management (ISFM) was also evaluated, -1 comparing all cropping systems with the addition of 24 kg N ha^{-1} inorganic fertilizer to a -1 continuous maize N-rate study (0, 24 and $92 \text{ kg of N ha}^{-1}$ fertilizer). This allowed estimation of a -1 N-fertilizer equivalency for ISFM maize in year two, which varied from 18 to $55 \text{ kg of N ha}^{-1}$. Overall, legume presence increased maize yield by 69-200% compared to sole crop, unfertilized maize. A farmer preference survey showed a preference for GNPP/maize rotation even though this system did not optimize yield, followed by pigeonpea/maize rotation, and lastly MZPP/maize systems. Farmers’ choices were based on cropping systems that provide multiple benefits.

Citation: Mhango WG (2011). Nitrogen budgets in legume based cropping systems in northern Malawi, PhD Dissertation, Crop and Soil Sciences, Michigan State University. East Lansing. USA. Michigan. East Lansing. 275pp

A11.2 Rotation of soybean/pigeon pea and maize/ green manures intercrops with maize

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Soils in Malawi have become very low in organic matter and nitrogen content, a situation creating complete dependence on inorganic fertilizers. Unfortunately, the prices of inorganic fertilizers have more than tripled within the recent decade making the fertilizers unaffordable for smallholder farmers. The increase in soybean production among smallholder farmers in Malawi would act as a source of nitrogen but unfortunately, soybeans have been observed to be net nitrogen transporters. An on-farm research aimed at developing a two-year short rotation system and determining the contribution of soybean and pigeon pea to the organic matter and nitrogen content of the soil was initiated in the 1996/97 season. The specific objectives were: to quantify the amount nitrogen fixed by the net legumes, to quantify the amount of organic C and nitrogen of the soil before and after residue incorporation and to evaluate the growth of maize due to the residual effect of the preceding legumes. There were four treatments compromising (1) an intercrop of soybean/pigeon pea, (2) maize undersown with *Crotalaria* (3) maize undersown with *Tephrosia* and (4) pure maize (the control) arranged in a split plot design. The maize plots were split into four nitrogen levels of 0, 20, 40 and 60 kg/ha . The cropping systems were assigned the main plots and the fertilizer N the sub plots. Trials on different farmers’ fields were taken as replicates for the experiment. Initial soil samples

were collected from each field to characterize the soil. Subsequently, soils were taken from four random points from each plot by using a sampling auger and a composite sample was made from the soil from the four points. The soils were analysed for total organic C, total N and pH. Total organic C was determined by the Walkley-Black method. Total N was determined by the Kjeldah method. N content of the maize as well as the legume plants was analysed using Colorimetric methods. The results showed non-significant differences ($P \leq 0.05$) in plant height, cob height, total dry matter, grain yield and N uptake between maize undersown with green manures and the control (pure maize). This is an indication that there was no competition between maize and the legumes undersown in the maize. Fertilizer N application significantly ($P < 0.001$) improved total dry matter, grain yield and N uptake of maize at all sites. The results of legume performance showed no significant differences ($P \leq 0.001$) in the amount of total biomass produced, residue biomass and N fixation by the different legumes. Biologically fixed N for soybean ranged from 31 kg/ha to 237 kg/ha, 48 kg/ha to 198 kg/ha and 83 kg/ha to 108 kg/ha at Songani, Kasonga and Bunda respectively. For pigeon pea, it ranged from 12 kg/ha to 78 kg/ha, -6 gk/ha to 39 kg/ha, and -83 kg/ha to -49 kg/ha at Songani, Kasonga and Bunda respectively. For *Crotalaria* and *Tephrosia* it was mostly negative at all sites. The results showed significant differences in subsequent maize responses to preceding legumes and the best performance was from the maize following soybean/pigeonpea intercrop. However, effects of preceding legumes at Kasonga were non-significant. As for the first season, inorganic fertilizer nitrogen application in the second season improved the response of the maize following the legumes at all sites thus an indication that N was still a limiting. Despite the non-significant effects of the preceding legumes to the subsequent maize at Kasonga, legume incorporation generally increased maize total dry matter from 8% to 48% at Songani, 8% to 9% at to 21% at Bunda. Grain yield of maize improved from 15% to 67% at Songani, 3% to 10% Kasonga and -5% to 20% at Bunda. N uptake increased from 13% to 60% at Songani, 5% to 7% at Kasonga and -6% to 21% at Bunda. Changes in the soil organic C, soil N and soil pH due to legume residue incorporation and fertilizer N application were non-significant ($P < 0.05$) an indication that a change in these parameter may not be possible in a short term since build up of these parameters is a slow process.

Citation: Madzonga OMM (2001). Rotation of soybean/pigeon pea and maize/ green manures intercrops with maize, Master of Science Thesis, Bunda College of Agriculture, University of Malawi. Lilongwe, Malawi

A11.3 Phosphorus use efficiency and productivity of pigeonpea [*cajanus cajan* (L.) millsp.] and soybean [*glycine max* (L.) merrill] on smallholder farms in different agro-ecological zones of central Malawi

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Low soil fertility especially nitrogen (N) is one of the major constraints to increased maize productivity on smallholder farms in Malawi. Integration of grain legumes in maize based systems is one of the strategies to improve soil fertility and yields as legumes fix atmospheric nitrogen through a symbiotic relationship with *Rhizobium* bacteria. A study was conducted in the 2013/2014 growing season in Linthipe and Golomoti Extension Planning Areas (EPAs) in Dedza District, and Nsipe EPA in Ntcheu District. The objectives of the study were to evaluate the grain yields and biological nitrogen fixation (BNF) of the sole and intercropped pigeonpea and soybean under two levels of inorganic P fertilizer (0 and 14 kg P ha⁻¹) and to determine the Phosphorus use efficiency (PUE). BNF was assessed using the N difference method. The experiment was laid out in a randomized complete block design (RCBD). Soils were sandy clay loams, loamy sand and sandy loams to sandy clay loams for Linthipe, Golomoti and Nsipe respectively. Soil pH was moderately acidic to acidic, pH 4.9 to 5.8 in the three sites. Available soil P (Mehlich-3) averaged 44, 84 and 39 mg kg⁻¹; and the mean soil organic matter (OM) were 3.26, 1.63 and 2.71% for Linthipe, Golomoti and Nsipe EPAs, respectively. Soybean grain yields were not affected by cropping system. However, intercropping significantly reduced pigeonpea grain yield by 47%. Similarly, BNF of soybean was not affected by cropping system while that of pigeonpea was reduced by 41% on per crop basis, with intercropping. Overall, intercropping of pigeonpea and soybean was efficient in resource utilization than sole cropping with land equivalent ratio (LER) of 1.44. On area basis, total BNF of the soybean + pigeonpea intercrop system was 90 kg ha⁻¹ which was 67 and 38% higher than the BNF of the sole crops of soybean and pigeonpea, respectively. Site and P fertilizer interaction effects were significant on grain yield and N fixed by soybean. P fertilization increased grain yields of both the sole and intercropped soybean in the mid altitude areas of Linthipe, $p=0.002$ and Nsipe, $p=0.037$. Similarly, P fertilizer increased BNF in both sole and intercropped stands of soybean in Linthipe, $p=0.039$ and Nsipe, $p=0.002$ over unfertilized. However, P fertilization had no significant effect on soybean grain yields and BNF in the low altitude area, Golomoti. Pigeonpea grain yields and BNF were not affected by P fertilizer at Nsipe and Golomoti EPAs. The PUE values for soybean were 56.9, 25.7 and 41.6 for Linthipe, Golomoti and Nsipe EPAs, respectively and those for pigeonpea were 20.1 and 23 for Golomoti and Nsipe EPAs, respectively. This study showed that intercropping of soybean with pigeonpea and application of inorganic P in mid altitude areas, offer good option for increasing grain yields of the legumes and improves soil fertility through biological nitrogen fixation that consequently lower smallholder farmers' cost of production.

Citation: Lupenga E (2016) Phosphorus use efficiency and productivity of pigeonpea [*cajanus cajan* (L.) millsp.] and soybean [*glycine max* (L.) merrill] on smallholder farms in different agro-ecological zones of central Malawi.

, Master of Science Thesis, Lilongwe University of Agriculture and Natural Resources. Lilongwe, Malawi

A11.4 Towards increased adoption of grain legumes among Malawian farmers - Exploring opportunities and constraints through detailed farm characterization

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Legume technologies are often promoted to increase nutrition, livelihoods and soil fertility of sub-Saharan smallholder farmers. Differences between regions as agro-ecological potential, market access and off-farm income opportunities and differences between farmers in terms of resource endowment and livelihood strategy imply that blanket recommendations for legume technologies are unlikely to be effective. Identification of niches through detailed system characterization, with the use of a farm typology to deal with the enormous diversity in smallholder farms, is an opportunity to improve both recommendations and their targeting. Fine-tuning recommendations to the farm type level will probably improve adoption by farmers and make legume-based development projects more effective. The results of farm characterizations, covering diverse farm types in Mchinji and Salima district in central Malawi, were used to gain insights in the possibilities of legumes to increase nutrition, livelihoods and soil fertility. Maize was the dominant staple food crop in both regions. Tobacco was a major cash crop in Mchinji, whereas cotton, tobacco and groundnuts were the most common cash crops in Salima. Although the area under legume cultivation was smaller in Mchinji than in Salima, groundnut had high adoption rates in both regions. Soyabean, beans and cowpea had low adoption rates and were allocated only very small areas. Farmers themselves defined the boundaries within which legumes can expand on their farm by food security and income. These were bordered and influenced by highly dynamic socio-economic, agronomic and biophysical factors. Although labour use efficiency of maize was generally higher than that of groundnut, legumes were economically more profitable than maize. Since maize is perceived as the main food security crop, the majority of the farmers indicated that legumes can only be expanded when domestic maize production is sufficient to satisfy household demand. Low resource endowed households were generally less food secure than medium or high resource endowed households and mentioned lack of cash for seeds and lack of land and labour as the major production constraints to expanding legume production. This indicates that targeting low resource endowed farmers who cannot be self-sufficient in maize production with legume technologies is unlikely to be successful. Although legumes did not have the potential to generate as high net benefits as tobacco or cotton, they were less risky in terms of possible negative net benefits and required less establishment costs. Therefore, cultivating legumes can be an option to generate some cash as well as to fortify diets with good quality protein for subsistence oriented farmers who are already self-sufficient in maize production. Marketability of legumes other than groundnut was often a major constraint for market oriented farmers to expanding their production. Farmers of all types were less interested in the potential soil fertility benefits of legumes. Current contributions of legumes to soil fertility are likely to vary among farms and fields due to (1) probable variable rates in biological nitrogen fixation and biomass production, notably due to variable soil fertility within farms and the preferential allocation of legumes to less fertile fields and (2) differences in residue management to store nutrients over the dry season.

Citation: Greta van den Brand, (2011). Towards increased adoption of grain legumes among Malawian farmers - Exploring opportunities and constraints through detailed farm characterization, Master of Science of Thesis, Environment and Biodiversity, Utrecht University & Wageningen University.

A11.5 Maize responses to organic matter additions from legume based cropping systems and compost manure in Kandeu and Manjawira extension planning areas, Ntcheu district.

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A study was carried out in 2011/2012 and 2012/2013 growing seasons in Kandeu and Manjawira Extension Planning Areas (EPAs) in Ntcheu district, Central Malawi, to determine maize response to crop residue incorporation from legume cropping systems and compost manure. This study was carried out with the understanding that legumes can contribute to soil fertility improvement through biological nitrogen fixation and the crop residue incorporated in the soil can turn into organic matter which is an essential component of soil fertility. In the first year, maize with or without compost manure, sole and intercropped legumes (pigeon pea, groundnut, soyabean and cowpea) were planted. In the subsequent season, maize was planted on the same plots to test the effects of legume crop residues incorporated in the soil on soil fertility. In both EPAs in the second year, all maize following legume cropping systems and compost manure were supplemented with 24 kg N ha⁻¹ as an integrated soil fertility management strategy. The experiments were laid out in a randomised complete block design with farms serving as replicates. Soil organic matter significantly ($p = 0.034$) improved following various legume cropping systems in Manjawira EPA whereas in Kandeu EPA it did not. There were no noticeable changes in soil inorganic nitrogen (NO₃-N) following legume cropping systems in the two EPAs. Maize grain yields following incorporation of legume crop residues was significantly ($p < 0.001$) different from continuous maize supplemented with 24 kg

N ha⁻¹ in both Kandeu and Manjawira EPAs. Also, there were significant differences ($p < 0.001$) in the yield of sole-cropped unfertilised maize, maize with inorganic fertiliser and maize with compost manure across different farms in Kandeu EPA. Maize grain yields were 1496, 2638, 3159, 2736, 3542, 2622, 2745, 2944 and 2763 kg ha⁻¹ for unfertilised maize; maize with 24 kg N ha⁻¹; maize with 92 kg N ha⁻¹; maize with compost manure; maize with crop residues from sole groundnut; groundnut intercropped with pigeonpea; sole soyabean; soyabean intercropped with pigeonpea; and sole pigeonpea supplemented with 24 kg N ha⁻¹; respectively. Incorporating crop residues from sole and doubled-up legume cropping systems, supplemented with 24 kg N ha⁻¹ in the second season did not result into significantly different maize grain yield in both Kandeu and Manjawira EPAs. In Manjawira EPA, there were no significant differences in maize grain yields at different fertiliser rates as well as nitrogen source, with grain yields averaging 1989, 2667, 2344, 2211, 2438, 2270, 2197, 2207 and 2419 kg ha⁻¹ from maize with 0 N, 24, 92 kg N ha⁻¹, compost manure, maize with crop residues from sole cowpea, cowpea intercropped with pigeonpea, sole groundnut, groundnut intercropped with pigeonpea and sole pigeonpea supplemented with 24 kg N ha⁻¹, respectively. In both EPAs, risk assessment showed that maize grain yield from maize following sole cowpea, sole pigeonpea, sole soya bean, cowpea intercropped with pigeonpea and groundnut intercropped with pigeonpea and maize with compost manure was equal to or greater than 1300 kg ha⁻¹ at 25% risk. This grain yield was above that of continuous maize with 92 kg N ha⁻¹. This implied that if adopted, maize grain yield following legume cropping systems and compost manure posed much less risk of harvesting maize grain below the household requirement in the low yielding domain. Therefore, organic matter addition in the soil from various legume cropping system, supplemented with low nitrogen inputs from inorganic fertiliser offer a viable option for improving maize grain yield rather than depending on inorganic fertiliser alone

Citation: Kalasa J.B. (2016). Maize responses to organic matter additions from legume based cropping systems and compost manure in Kandeu and Manjawira extension planning areas, Ntcheu district. Master of Science Thesis, Lilongwe University of Agriculture and Natural Resources. Lilongwe, Malawi

A11.6 Effects of planting density on growth and yield components of cassava and cowpea intercrops in Malawi and Mozambique

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Wide row spacing is one of the major limiting factors for improved crop yields of cassava and cowpea intercrops. A trial was conducted at two sites at students' farm under the crop Department of Crop and Soil Science, Bunda College of Agriculture, Lilongwe District, Malawi and at Ntengo Umodzi Research Station, Tete Province, Mozambique to evaluate the effect of planting density on the yield of cassava and cowpea. The trial was designed as split plot with main plot as four row spacing levels of 1.0 m x 1.5 m (6666 plants/ha), 1.0 m x 1.2 m (8333 plants/ha), 1.0 m x 0.9 m (11111 plants/ha) and 1.0 m x 0.6 m (16666 plants/ha) and sub-plot cropping system two levels, cassava monocropped and cassava/cowpea intercropped and replicated four times. Data collected on the trial was analyzed using General Statistical (GenStat 14th Edition) and SPSS version 16.0 computer packages. The results showed that there were significant ($p \leq 0.001$) reduction in cassava yield components (number of tubers and tuber weight) and growth parameters (tuber length, tuber diameter, plant height and canopy diameter) in response to spacing. Significant interactions ($p < 0.001$) were also observed among spacing x sites (S x L), as well as sites (L). The correlation analysis showed that yield components (tuber number per plant and number of branches per plant) were positively correlated with tuber yield at both sites. On the other hand the correlation analysis on cowpea, showed that yield components (pods number per plant, seeds per pods and a 100 seed weight) and growth parameters (plant height, pod length, harvest index, number of branches per plant and length of the braches per plant) were positively correlated with grain yield at both sites. For the cassava growth parameters, 1.0 m x 0.6 m spacing cassava/ cowpea intercrop had highest values of plant height, number of branches per plant followed by 1.0 m x 1.5 m, 1.0 m x 1.2 and 1.0 m x 0.9 m. For biomass and canopy diameters, 1.0 m x 1.5 had the highest values on canopy while the 1.0 m x 1.2 m produced the highest biomass yield and the least was 1.0 m x 0.6m spacing of cassava/cowpea produced the highest tuber length of 38.6 cm and 13.1 t/ha tuber weigh and the least 1.0 m x 0.6 spacing was 34.39 cm tuber length and 10.2 t/ha tuber weigh. For tuber number and yield, 1.0 m x 0.6 m spacing cassava/cowpea and cassava alone had the best values of 13 and 37.19 t/ha and lowest values of 7 and 18.88 t/ha cassava/cowpea and cassava alone obtained 1.0 m x 1.5 spacing at both sites. The highest LER of 2.34 was obtained at 1.0 m x 1.5m spacing and lowest LER of 1.86 was obtained from 1.0 m x 1.2 m spacing at Bunda College and at Ntengo Umodzi, highest LER of 1.68 and 1.64 were obtained at 1.0m x 0.9 m; 1.0 m x 1.5 m and lowest LER of 1.59 was obtained from 1.0m x 0.6 m. The highest SPI of 1514.09 and 1454.56 were obtained at 1.0 m x 0.6m at both sites and lowest SPI of 454.26 and 323 were at 1.0 m x 1.5 m at both sites, Bunda College and Ntengo Umodzi.

A11.7 Influence of *Tephrosia vogelii* combined with inorganic fertilizer on maize (*Zea mays*) using biomass transfer technology

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Maize production in Malawi is constrained by high costs and hence sub-optimal use of chemical fertilizers under continuous cultivation. Optimization the use of biomass of leguminous species as low- input soil fertility replenishment is a viable option. However, scientific information inadequate on the appropriate rates of inorganic fertilizer necessary to combine with green manure like for tree species *Tephrosia vogelii* on maize. A field experiment was conducted at Bunda College of Agriculture on the teaching and research farm of the Department of Crop and Soil Sciences, to evaluate the effect of application of *Tephrosia vogelii* leaf biomass combined with and without inorganic fertilizer, on yield of maize crop using a biomass transfer technology. An experiment was a 2x2x3 factorial arrangement replicated 3 times in a randomized complete block design with the following factors: (1) *Tephrosia vogelii* biomass application at two rates (0 and 3 t/ha), (2) time of *Tephrosia vogelii* biomass at two times (two months before planting and three weeks after planting) and (3) inorganic fertilizers at three rates (0, 11.5, 23, 46 and 92 kg /ha of nitrogen.). The following parameters were highly correlated with each other; soil nitrogen, chlorophyll content, plant height, seed size, biomass yield and grain yield at $p \leq 0.001$. combination of inorganic fertilizers rate of 92 kg N/ha with 3 ton/ha of *Tephrosia vogelii* was the best treatment having given the highest grain yield (6.2 t/ha), high level of nitrogen in the soil, high plants, highest levels of chlorophyll, nitrogen build up and highest residual nitrogen in the soil. On the other hand, control or small doses of inorganic fertilizers (12.5 and 25 kg /ha of 92 kg N/ha; 11.5 and 23 kg N/ha respectively) gave low levels of the same variables. The application of 3 tone/ha of *Tephrosia vogelii* alone gave lower (1.5t/ha if applied before planting and 3.1t/ha if applied after planting) maize grain yield than that when 92 kg N/ha (5.1 t/ha) was applied; combination of *Tephrosia vogelii* with reduced rate of inorganic nitrogen fertilizer increase maize yield by more than 1 t/ha; *Tephrosia vogelii* combined with inorganic fertilizer gave positive balance of nitrogen in the soil. The 3 t/ha of *Tephrosia vogelii* applied after planting in combination with only 25 % (23 kg N/ha) of 92 kg N/ha (recommended) of inorganic fertilizer gave maize yield comparable to that with 92 kg N/ha inorganic fertilizer alone. The 3 t/ha of *Tephrosia vogelii* applied two months before planting gave a substitution value of 0.66% whereas the 3 t/ha of *Tephrosia vogelii* applied after planting gave a substitution of 0.89%. It was concluded that (i) 23 kg N/ha is the small dose to combine with 3t/ha *Tephrosia vogelii*; (ii) combining inorganic and organic sources of nitrogen is beneficial. Further research is recommended to determine the effect of using different rates of *Tephrosia vogelii* with small doses of inorganic fertilizers, and quantify economic benefits of using *Tephrosia vogelii* in maize production. Another study should be done to determine the effect of time of application of biomass; the economic benefits associated with these practices.

Citation: Manhique LF 2014. Influence of *Tephrosia vogelii* combined with inorganic fertilizer on maize (*Zea mays*) using biomass transfer technology. MSc Thesis. University of Malawi. Malawi

A11.8 Effects of soybean residues and inorganic fertilizer nitrogen on maize production under smallholder farming systems in Zomba, Malawi

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An on farm trial was conducted at Songani and Kasonga, Malosa Extension Planning Area (EPA) in Zomba RDP (Southern Malawi) to examine the combined effect of applying inorganic fertilizer N and soybean (*Glycine max* (L) Merr.) crop residues to the soil on the yield of subsequent maize crop. Soybean varieties Ocepara 4, Bossier (specific varieties), and Kaleya and Magoye (promiscuous varieties) and maize were planted in farmers' fields in the 1996/97 crop season. After harvest, the crop residues were incorporated in the respective plots. All plots were grown to maize in the 1997/98 crop season after incorporation the crop residues from the first season. The average organic nitrogen ranged for 15 kg N/ha for maize stover to 76 kg N/ha for soybeans. Fertilizer inputs were 0, 20, 40, 60 kg N/ha and 0, 9, 18, 27 kg P/kg the sources of fertilizer N and P were Calcium Ammonium Nitrate (CAN) and 23:21:0+4S. Generally, the performance of the specific varieties was better than that of promiscuous varieties as observed by the greater grain and total dry matter production. The promiscuous varieties and had harvest index (HI) and nitrogen harvest index (NHI) than the specific varieties. Ocepara 4 produced high stover production and N accumulation at Songani, while Magoye had the least stover N accumulation at Songani. Magoye produced more stover at Kasonga, but the accumulation of N was similar with all varieties. In 1997-98 season, maize grain yields were significantly different due to location ($p < 0.001$), fertilizer rates ($p < 0.001$) and the type of crop residue ($p = 0.002$) applied. There was an increase in maize yield as fertilizer N application was increased. Maize following maize gave low yields as compared to maize grown after the soybeans. Overall grain yields were much higher at Songani (2341 kg/ha) than at Kasonga 835 kg/ha). Total N uptake by maize was significantly affected by location and fertilizer N rates. Increase in fertilizer resulted in increase in N uptake by maize. The highest N uptake was from plots which received Bossier and Magoye residues in combination use of fertilizer with maximum fertilizer rates at Songani and Kasonga, respectively.

The combined use of fertilizer and soybean proved an effective strategy to increase subsequent maize yields and percent organic carbon of the soil.

Citation: Mwato I L (2000). Effects of soybean residues and inorganic fertilizer nitrogen on maize production under smallholder farming systems in Zomba, Malawi, MSc. Thesis, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

A11.9 Assessment of the soil fertility in selected potato growing sites in Malawi and determination of optimal NPK (8:18:15+6S) level for potato production (*Solanum tuberosum* L) in Bembeke, Dedza

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Two studies were conducted in selected growing areas in Malawi as contribution towards the development of site-specific and financially viable fertilizer recommendations for potatoes. The first study was carried out in 2010 aimed at evaluating the soil fertility status of selected potato growing areas in the country. A soil survey using the grid method was conducted in all sites during which morphological properties were evaluated. Soil samples were collected from the top soil (0 -30 cm) at grid points. The samples were analyzed for nutrient content, particle size distribution, organic matter and soil reaction. The soil survey and the analytical study revealed, on average, deficiencies of phosphorus in Bembeke (2.19 mg/kg), Tsangano (1.19 mg/kg) and Sera soils (3.2 mg/kg) and adequate levels at Bvumbwe (30.2 mg/kg) and Biriwiri soils (98 mg/kg). Nitrogen and potassium were deficient in all surveyed sites. The soil reaction varied across the sites from strongly acidic (4.7) in Tsangano Research Sub-Station, to moderately acid (5.9) in Biriwiri. Among the micronutrients assessed, iron was very abundant in all surveyed sites. The study showed high availability in soil fertility from one potato growing area to another. This implies that blanket fertilizer recommendations should be site-tailored. The study recommends the application of lime to raise the pH in Tsangano Research Sub-Station, Sera and Bembeke Research Sub-Station soils. These areas have low pH values below the optimum range (5.2 -6.5) for potato production. The second study conducted at Bembeke Research Sub-Station in Dedza, in the 2010/11 rainy season, investigated the effect of an NPK (8:18:15+6S) fertilizer type on potato (var. Violet) yield and associated economic variability. The study comprise nine treatments which were laid out in a complete randomized block design with three replicates. The treatments were 0, 50, 100, 150, 200, 250, 300, 350 and 400 kg/ha of NPK fertilizer. Path coefficient analysis was conducted to ascertain the contribution of foliar N, P and K contents to the total tuber yield. Economic analysis for the application of the NPK fertilizer was done using the partial budget technique. Application of NPK (8:18:15+6S) fertilizer significantly increased tuber yields. The maximum marketable and total yield (5.8 t/ha and 11.5 t/ha, respectively) were obtained with application of 400 kg/ha which was the highest rate. However, economic analysis revealed that 250 kg/ha was financially viable for the resource constrained farmers in the area since it had the highest marginal levels of the fertilizer. Path coefficient analysis technique showed that these nutrients contributed to tuber yield individually and in the conjunction with each other. Phosphorus made maximum direct contribution (77.3%) towards the tuber yield and played a major enhancement role for nitrogen and potassium towards the same.

Citation: Gomagoma L, (2014). Assessment of the soil fertility in selected potato growing sites in Malawi and determination of optimal NPK (8:18:15+6S) level for potato production (*Solanum tuberosum* L) in Bembeke, Dedza. MSc. Thesis University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

A11.10 Effects of inoculation, inorganic fertilizer and potassium fertilizers on yield and nitrogen biological fixation of soybean (*Glycine max* (L) Merr.) in Mchinji district

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Clinton Development Initiative's (CDI) anchor farm significantly increases its soybean yield when they applied a new NPK fertilizer and rhizobia. However it was not known whether the yield increase was due to the rhizobia inoculum or the new NPK fertilizer. The current study was conducted to address this problem. To this end, a field experiment was conducted at the CDI anchor farm (Mphelero Farm) in Mchinji district of Central Malawi during the 2012/13 crop growing season. The objective was to determine the effect of fertilizer application and rhizobia inoculation on biological nitrogen fixation, soybean yield and the N, P K levels in soybean plants. Factors under study were inoculation, phosphorus and potassium. Two, three and four levels of inoculation (inoculated and uninoculated), P₂O₅ (0, 20 and 40 kg/ha) and K₂O (0, 20, 30 and 40 kg/ha) were used respectively. Thus this study was laid out as a 2 x 3 x 4 factorial arrangement in a randomized complete block design replicated three times. To evaluate BNF, the difference method was used using maize as a reference crop. Results indicated that P application significantly increased BNF with highest (92 kg/ha) N fixed when 20 kg P₂O₅ was applied. Grain yield was significantly increased by P application and optimum application rate was 20 kg/ha. Inoculation significantly increased soybean grain yield (by 26 %) and BNF. Potassium application increase K content in

soybean plants with highest level (0.22) observed when 30 kg/ha K was applied. There was significant interaction between P and K on nitrogen content and maximum concentration was attained at 20 and 30 kg/ha respectively (2.99%). From this study, 20 kg/ha of P₂O₅ or 20 kg K₂O₅ inorganic fertilizers or inoculation increased soybean yield and BNF at Mphelero farm.

Citation: Chunga P.Z. 2016. Effects of inoculation, inorganic fertilizer and potassium fertilizers on yield and nitrogen biological fixation of soybean (*Glycine max* (L) Merr.) in Mchinji district. Master of Science Thesis, Lilongwe University of Agriculture and Natural Resources. Lilongwe, Malawi

A11.11 Response of grain legumes to phosphorus and Sulphur fertilization in maize-legume short term rotation system in Northern Malawi

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On farm trials were carried out at Champhira and Nchenachena Extension Planning Areas (EPAs) in Mzuzu Agricultural Development Division (MZADD) in the 1999/00 and 2000/01 cropping seasons to determine the effect of phosphorus and Sulphur on the performance of legumes and their effect on subsequent maize crop. The trials were researcher designed but farmer managed with five farmers in each EPA as single replicates. In the 1999/00 cropping season, groundnut (*Arachis hypogaea*), Bambara groundnut (*Vigna subterreanean*), Soybean (*Glycine max* L (Merr), and maize (*Zea mays*) were grown with and without nitrogen, phosphorus and Sulphur mineral fertilizer. In the 2000/01 cropping season, maize was grown in all plots as attest crop and received top dressing of 50 kg N /ha from Urea. Soil chemical analysis has showed that application of phosphorus and Sulphur to the legumes increased sulphate-sulphur and available phosphorus, but had not effect on total nitrogen, total phosphorus and organic carbon. However, the sites values were significantly different ($p=0.001$) with Nchenachena having higher values except for available phosphorus compared with Champhira. This suggested that soils at Nchenachena fixed more P. Soybean and groundnut recycled more P in the stovers than Bambara groundnut and maize. In the 1999/00 cropping season, a positive response to rate of P and S application was observed in maize and soybean grain yield, but there was no effect on groundnut and Bambara groundnut yields. The site x crop interaction was significant ($p<0.001$) for grain yield. Groundnut and Bambara groundnut yielded higher at Nchenachena than at Champhira. Stover yield increased with application if phosphorus and Sulphur in all crops ($p<0.01$) except Bambara groundnut at both sites. Groundnuts and Bambara groundnut produced more stover at Nchenachena, and maize and soybean at Champhira. ANOVA of maize grain yield in the second season (2000/01 season) showed significant effects of sited and fertilizer application ($p=0.001$) and the type of crop residues that were incorporated ($p=0.003$). Legume residues from fertilized treatments increased maize grain yield at Champhira by 31.60 %, 34.26%, and 34.31% in plots previously planted with groundnut, Bambara groundnut and soybean respectively. Maize following legumes gave higher grain yield (1223-1445 kg /ha) than maize -maize rotation (798 kg/ha). These results are discussed in the context of applying phosphorus and Sulphur to increase legume stover production before they are incorporated in the soil manure for the subsequent maize crop.

Citation: Mhango W.G (2002) Response of grain legumes to phosphorus and Sulphur fertilization in maize-legume short term rotation system in Northern Malawi. MSc Thesis. University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.12 Contribution of promiscuous and specific soybean variety residues to soil fertility improvement and maize yield under smallholder farms in Zomba district, Southern Malawi

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An on-farm research was conducted in two growing seasons of 1999/2000 and 2000/2001 in two different watersheds, namely Songani and Kasonga, in Malosa Extension Planning Area (EPA) in Machinga Agricultural Development Division (ADD). Songani (900masl) is cooler characterized by acid soils (pH 4.5). Two year short term legume/maize rotation field experiment laid out in a split-split plot in a completely randomized block design were established on farmers' fields. The study aimed at determining soil fertility improvement potential of promiscuous and specific soybean varieties, and their effects on subsequent maize yields. The biological nitrogen fixing potential of four soybean varieties. I.e. two promiscuous (Kaleya and Magoye) and two specific (Bossier and Ocepara 4) were estimated using the Nitrogen Difference (ND) method and the Harosoy soybean varieties which does not fix nitrogen. There were significant differences due to site. The legumes produced more leafy biomass and fixed more N at Songani than at Kasonga. It was found that Magoye produced more biomass (3996 kg/ha) than the other varieties. It fixed 75 kg N/ha at Songani. The specific variety Ocepara 4 produced 2889 kg/ha of biomass and fixed some 52 kg N/ha at Kasonga. Soybean residues supplemented with mineral nitrogen fertilizer greatly improved subsequent maize yields. Maize grain yield following Magoye supplemented with 40 kg N/ha of mineral nitrogen were highest (2707 kg/ha) at Songani, while maize after Ocepara 4 applied with 60 kg N/ha produced yields at Kasonga (622 kg /ha). Significant differences of maize grain yields were observed

between the two sites. Songani had a mean grain yield of 1329 kg/ha, whereas Kasonga averaged 472 kg/ha. Evaluation of nodule count and nodule effectiveness revealed that promiscuous Magoye at Songani had a higher number of small size effective nodules per plant than other varieties. Specific varieties, Ocepara 4 at Kasonga had more effective nodules per plant of large sizes. It was concluded that size had significant influence on the productivity of soybean. The promiscuous Magoye and specific Ocepara 4 produced more biomass and fixed more nitrogen than other varieties at Songani and Kasonga, respectively. Maize grain yield following soybean these varieties supplemented with fertilizer nitrogen, were significantly different from the other varieties. Further study to characterize and quantify the indigenous rhizobia strains in these two areas would be necessary.

Citation: Nkhuzenje H. 2003. Contribution of promiscuous and specific soybean variety residues to soil fertility improvement and maize yield under smallholder farms in Zomba district, Southern Malawi. MSc Thesis. University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.13 Assessment of soil fertility status using conventional and participatory methods

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A study to determine where the opinion of local farmers and scientists converge in the assessing the soil fertility was carried out in Zomba District, Southern Malawi. Participatory methods were used to elicit farmer perception and assessment of soil fertility status. Laboratory methods were carried out to assess the actual nutrient fertility and textual status of the soil. The soil samples used in the paired comparison came from fairly uniform patches in the farmers' fields, jointly- identified by the researchers and the farmer. The properties of an ideal soil were registered to include the dark color of the soil, consistence of the decaying material, high soil moisture retention capacity, and the incidence of tall vigorous vegetation. This coincided with the conventional opinion, that organic matter, soil mineral nutrients, soil colour and soil texture were the most closely associated parameters inferred from the farmer to what is measured in the laboratory. Farmers used matrix ranking to score their soil attaching relative values related to soil fertility parameters, on a 1-4 scale. The laboratory soil parameters were sorted in grouped according to a 1-4 threshold scale. Farmer and scientist values formed a bivariate pair of the data set. Correlation between the bivariate data pair was measured. Participatory methods revealed that a high density population has forced farmers into continuous mixed cropping and cultivation of steep fragile ecosystems resulting in land degradation through erosion of top soils an organic matter. Organic matter and dark color of soils were considered by farmers to be central to soil fertility. A high incidence of intercropping pigeon pea, cassava and maize was observed. There was a high and significant correlation between farmer and scientist perceived soil fertility values, particularly on laboratory measured organic matter and the farmer-perceived overall fertility of the soil it was concluded that if farmer's perception and participation is central to the development of soil improving technologies, then organic matter technologies aimed at improving soil fertility have potential for adoption. Technologies that have similar spatial crop arrangement as the predominant intercropping systems have a chance to succeed.

Citation: Kamangira J.B, (1997). Assessment of soil fertility status using conventional and participatory methods, MSc. Thesis, University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.14 Assessing the potential of improving maize yield using legume residues and Thundulu Rock Phosphate

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An experiment was conducted in the 2007/08 growing season in Mkanakhothi Extension Planning Area (EPA), of Kasungu Rural Development Project (RDP) in Kasungu Agricultural Development Division (ADD). The main objective of this study was to assess the potential of increasing maize yield the use of legume residues and Thundulu Rock Phosphate (TRP), with the following as specific objectives; (i) to characterize the socio-economic stratum, soil and cropping systems of the study area, (ii) to evaluate the effect of application of legume leaf biomass, TRP and the combination of pigeonpea leaf biomass and TRP on soil organic matter, nitrogen, phosphorus, soil pH and maize yield, (iii) to determine the effect of double up legume and cereal legume intercrops on the amount of nitrogen fixed in the plant tissues, (iv) to evaluate the effects of maize/groundnut intercrop and TRP on soil pH, nitrogen, phosphorus, maize and groundnut yield. Crop yield response to sole application of either organic or inorganic soil nutrient sources and the application of these soil nutrient sources in the combination were evaluated. Legumes that were intercropped with maize were pigeon pea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*). The crop yield responses to the sole maize, the sole groundnut, and the maize/groundnut or double up legumes (groundnut/pigeon pea intercrops were evaluated. In the study the mother baby trial approach was used. The mother trail (researcher designed and managed), involved eight farmers while the baby trial (farmer managed) involved twenty four farmers. In both cases farmers served as replicates. Treatments were laid out in a randomized complete block design. The results of this study have shown that the combined application of legume residues and TRP to the soil can improve maize yields. Further studies should consider different rates of pigeonpea biomass plus TRP acidulations. Such work should also include evaluating residual effects of the combined application of

pigeon pea biomass and TRP.

Citation: Phiri AT. Assessing the potential of improving maize yield using legume residues and Thundulu Rock Phosphate. MSc Thesis. University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.15 Effects of *Sesbania sesban* and *Tephrosia vogelii* on maize yields at three landscape positions in Southern Malawi

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A study was conducted in Zomba, Southern Malawi to compare the effects of *Sesbania sesban* and *Tephrosia vogelii* on maize yields at three landscape positions. Farmers' fields were used as replicates and were selected based on those who were practicing intercropping of maize (*Zea mays*) with pigeon pea (*Cajanus cajan*) as a multipurpose tree. Each farmer's field had 3 plots of 15 m by 15 m. The treatments included; (a) maize with *Sesbania sesban*, (b) maize with *Tephrosia vogelii* and (c) sole maize (the control). Maize was planted at a population of 37000 plants/ha while multipurpose trees were planted at 7400 plants/ha. *Sesbania sesban* was established from seedlings while *Tephrosia vogelii* was direct seeded. Soil samples were taken at the depth of 0-15 cm to determine the initial soil fertility status prior to introduction of multipurpose trees as shrubs (MPTs). Growth and yield measurements of MPTs included tree height, stem diameter at 20 cm from the ground, number of primary branches per plant, woody and leafy biomass yields. Maize yield and yield components included maize grain and stover yields, harvest index, weight of cobs, cob length and seed size. Plant tissue analysis was done to determine nitrogen content and contribution by the MPTs. Plant survival, stem diameter at 20 cm from the ground, plant height, number of primary branches per plant, leaf and woody biomass yields of *Sesbania sesban* were significantly ($P < 0.05$) higher on the dambo valley than the dambo margin and the steep slope landscape positions. As for *Tephrosia vogelii*, the response variables were not affected by the landscape positions. Nitrogen contents and yields of both *Sesbania sesban* and *Tephrosia vogelii* were not significantly different across the landscape positions. In both years, maize and stover yields were significantly higher ($p < 0.05$) on the dambo valley than on the steep slopes but not significantly different with those of the dambo margin. In the first year of MPTs establishment, maize grain yields ranged from 1376 kg/ha in the control system to 1473 kg/ha in the *Tephrosia vogelii* system, but these yields were not significantly different. The same trend was true for stover yield and yield components. Following first incorporation of leafy biomass, the *Sesbania sesban* system gave significantly ($p < 0.05$) higher grain maize yields and yield components than *Tephrosia vogelii* and the control systems in the second year. The study has shown that relay intercropping technology involving maize with *Sesbania sesban* established from bare rooted seedlings has potential for increasing smallholder maize production in the study area as opposed to the one involving maize with *T. vogelii* established directly from seeds. This is particularly so where the *S. sesbania* seedlings and *T. vogelii* seeds were transplanted and direct sown in the ridge furrows, respectively, in a ridge furrow system. Hence, those farmers with limited resources need to concentrate in the dambo valley and dambo margin landscape positions where the trees produce abundant leafy biomass for the improvement of soil fertility.

Citation: Phiri ADK. Effects of *Sesbania sesban* and *Tephrosia vogelii* on maize yields at three landscape positions in Southern Malawi. MSc Thesis. University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.16 Impact of existing and introduced agroforestry soil management technologies on smallholder maize production

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The study was carried out in Zomba, Malawi, in order to investigate the potential of introduced and existing soil management technologies on smallholder maize production. The study started with a survey of a random sample of 100 farmers followed by on-farm socio economic experimentation. The survey was conducted to get acquainted with the sociocultural characteristics of the farm families. The data was cross tabulated and the chi-squares were used to determine the relationship between household characteristics and farm production. A Cobb Douglas Production Function was then estimated to determine whether the systems returns to scale were constant, increasing or decreasing. Data from the Field Experimentation was analyzed using MSTATC statistical package and where means were significant separation was done using the Least Significant Difference (LSD). Results from the survey have indicated that there were not significant differences in the household socioeconomic characteristics. Average landholding size was 0.56 ha with a mean household size of 5.8 people. Maize based intercropping system was practiced with a mean maize yield of 714 kg/ha for local variety and 1320 kg/ha for hybrids. Results of the production function (significant at $p < 0.05$) have indicated that farmers produce within increasing returns to scale (Stage I) and there is need to invest on more organic fertilizer, labour and land to stretch to Stage II of production. Farmers have to intensify their use of resources such as land, labour and fertilizer to increase maize production. Use of legume species is one of the affordable ways of increasing crop yield by resource poor farmers with minimal inorganic fertilizer use.

The result have shown that labor requirements for the systems is within the households potential labour supply hence farmers can undertake the technologies without compromising other farm activities.

Citation: Kamanga B.C.G, (1999). Impact of existing and introduced agroforestry soil management technologies on smallholder maize production, MSc. Thesis, University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A11.17 Performance of maize under relay intercropping and the presence of vetiver grass hedges at three landscape positons in Southern Malawi

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A two year researcher and farmer managed was conducted in 2001/02 and 2002/03 seasons in Zomba Rural Development Project in Southern Malawi to determine soil chemical and physical properties, above ground multi-purpose tree biomass and maize production in relay intercropping under vetiver grass technology. The trial was factorial combination of three landscape positions (dambo valley, dambo margin and steep slope), two vetiver grass hedges (presence or absence) and five cropping systems namely; three organic systems involving *Sesbania sesban*, *Tephrosia vogelii* and *Cajanus cajan* relay intercropped with maize. In addition, there were two maize systems namely; maize only (unfertilized) and maize fertilized with 92 kg N/ha (full fertilizer rate for the study area. Each of the three organic systems was fertilized with 46 kg N/ha as a top dress. Data were collected on selected soil physical properties (initial) and chemical properties (at the beginning and the end of each season), maize grain yield, above ground biomass, and nitrogen content in leafy biomass. Initial soil physical and chemical properties deteriorated with increasing slope and depth. In subsequent analyses, soil nitrogen, phosphorus and organic matter were generally higher in vetiver plots than in non-vetiver plots and relay intercropping systems registered higher values of the elements than in pure maize systems. Dambo valleys remained generally superior in most soil chemical properties than the higher slopes. *Tephrosia vogelii* produced the highest above ground biomass ahead of *Sesbania sesban* and *Cajanus cajan* in that order while a general decline with increasing close was evident. On the other hand, the presence of vetiver grass hedges resulted in higher amount of leafy biomass than non-vetiver systems. Leafy biomass from *C. cajan* contained the most nitrogen (1.8 %) while *T vogelii* and *S.sesban* did not differ (1.5%) and leaf nitrogen content declined with increasing slope. Maize plots that received 92 kg N/ha produced the highest grain yields while te unfertilized maize produced the least in both years of study. The relay intercropping systems were intermediate in both years but increased by about 16% in the second year. Grain yields from intercropping systems were 48% and 46% superior to unfertilized maize in the first and second years respectively. On the other hand, grain yields from agroforestry systems were 53% and 64 % of the fully fertilized maize in the first and second years respectively. The presence of vetiver grass hedges resulted in higher grain yields in the second year by an average of 25% over the first- year yields across the landscape positions. However, grain yields declined with increasing slope.

Citation: Nyirenda C.L.M.)2007) Performance of maize under relay intercropping and the presence of vetiver grass hedges at three landscape positons in Southern Malawi. MSc Thesis. University of Malawi, Bunda College of Agriculture. Lilongwe, Malawi

A11.18 Comparative analysis of different irrigation technologies and water management technologies for dry season cultivation of beans (*Phaseolus vulgaris*) in Chingale Area Development Program (ADP), Zomba

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A study was carried out in the 2003 dry season (winter) to compare the agronomic, technical, socio-economic and financial aspects of different irrigation technologies and water management techniques for two advanced bean lines. Nine water management techniques using five irrigation technologies were studied in Chingale ADP in Zomba district in Southern Malawi. The technologies used encompassed motorized pumps, treadle pumps, water cans, gravity irrigation and one non-irrigated treatment. The treatments under study were according to the method of extraction, conveyance and application of water. The research studies found out that there were no significant differences ($p < 0.05$) in the amount of water supplied by different farmers to the bean test crops and these ranged from 32.9 to 1227.31 m³. The irrigation depth were not significant ($p < 0.05$). Grain yields were not significantly different ($p < 0.05$) across the treatments with mean yield of 1249 kg/ha in Type II and 712 kg/ha in Type IV line. Socio-economic analysis indicated the preponderance of male farmers (71) over female farmers (43) in dry-season bean cultivation. Differences between gross margins were highly significant across the treatments and between bean lines. The highest gross margins were noted in gravity irrigation seconded by the treadle pumps and the lowest gross margins were realized in motorized pumps were used for irrigation. It is recommended that farmers in Chingale should be advised to irrigate using gravity and treadle pumps for high yields and gross margins especially in the upland dambo areas.

Use of water cans in the delivery and application of water from hand dug wells should be used only when there is no alternatives because of drudgery from labour. Motorized pumps should be encouraged only when farmers are given support systems in order to break even.

Citation: Kadyampakeni D.M.S (2004). Comparative analysis of different irrigation technologies and water management technologies for dry season cultivation of beans (*Phaseolus vulgaris*) in Chingale Area Development Program (ADP), Zomba, MSc. Thesis, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

A11.19 The effect of phosphorus and sulfur on biomass production of green manure crops and that of the biomass on subsequent maize in Northern Malawi

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A study on the effect of phosphorus and sulfur on biomass production of green manure legume crops and the effect of the green manures on the subsequent maize yield was conducted during the 1999/2000 and 2000/2001 growing seasons. The study was conducted at two Extension Planning Areas of the Mzuzu Agricultural Development Division (ADD) in Northern Malawi. The Main objective of the investigation was to evaluate the response of green manure legume crops to phosphorus and sulfur application in terms of dry matter production and the manure's effect in subsequent maize yield. The study sites were Champhira and Nchenachena. Three legume green manure crops: *Mucuna Pruriens*, *Cajanus cajan* and *Tephrosia vogelii* and one cereal crop, *Zea mays* were planted as subplots and each crop received three levels of 0, 20 kg P₂O₅ and 4kg S, and 40 kg P₂O₅ and 8 kg S per hectare. At each site, the experiment was replicated times using farmers' plots in a 2*3*3 Split-split plot arrangement in a randomized complete block design (RCBD). The results revealed that there were significant differences among the four crops ($p=0.001$) in biomass production. *Mucuna pruriens* outperformed the other crops (54380 kg /ha) followed by *Tephrosia vogelii* (5258 kg/ha), *Zea mays* (4972 kg /ha) and *Cajanus cajan* (2669 kg/ha respectively). There were also significant differences ($p=0.001$) between crops species in terms of biomass production attributed to inorganic fertilizer rates. The lowest biomass production was recorded from the treatment without fertilizer input, and the highest biomass production was recorded from the treatment with the fertilizer rate. The two sites were significantly different ($p=0.001$) in terms of biomass production. Mean biomass yield at Nchenachena (5650 kg/ha) was higher than that obtained at Champhira (3490 kg/ha). Maize grain yields were significantly different at Champhira ($p=0.001$) and at Nchenachena ($p=0.01$). The grain yield was higher at latter (2328 kg/ha) than the former site (1206 kg /ha). In the subsequent growing season, maize grain and total dry matter produced were significantly different at ($p<0.01$) and ($p=0.001$) respectively attributed to the type crop preceding them. Maize grain and biomass after *Mucun pruriens* was the highest (1104 and 5170 kg/ha respectively) followed by that after *Cajanus cajan* (880 kg/ha and 4430 kg /ha), *Tephrosia vogelii* (785 and 3915 kg /ha) and *Zea mays* (627 and 3059 kg/ha) respectively from grain and total dry matter produced. Fertilizer application had no overall effect on increasing soil available phosphorus but soil levels still remained below sufficiency level. Inorganic fertilizer application also indirectly influenced soil bulk density since it increased the organic matter content of the soil through the higher amounts of dry matter incorporated, thereby reducing soil bulk density.

Citation: Mwalwanda A.B (2002). The effect of phosphorus and sulfur on biomass production of green manure crops and that of the biomass on subsequent maize in Northern Malawi, MSc. Thesis, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

A11.20 Soil fertility studies with compost and phosphate rock amendments at Lunyangwa and Bembeke Research Stations

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Mineralogy of acidic Tropical soils contributes to the problem of phosphorus (P) deficiency due to P sorption. The objectives of this research were to evaluate composting methods for improving the availability of phosphorus in igneous low grade (low reactivity) Thundulu phosphate rock (TPR) and to test its effect on maize (*Zea mays*) yield. The treatments included two composting materials namely, cattle manure and maize stover, which were applied at the rate of 3 t/ha. Phosphate rock which was composted was at three levels: 50 kg P₂O₅, 75 kg P₂O₅ and 100 kg P₂O₅/ha. Epigeic earthworms were introduced in three other phosphor-composts of manure. Sole manure and crop residue composts were also prepared. The three levels of phosphorus were also applied as direct application of phosphate rock. Single superphosphate was used as a standard treatment at the rate of 20 kg P₂O₅ / ha. Thus there 16 treatments in total. The experiment was arranged in a randomized complete block design (RCBD) with 4 replications. Soil analysis for P has shown no significant differences between treatments in improving the status of P in the soil at both Lunyangwa and Bembeke experimental sites at both sampling times (i.e at seedling and harvesting stage of maize) and between sampling times during both the first season (1997/98) and the second season (1998/99). All P values were below the critical point of P in the soil and therefore maize yields realized was far below potential of 5500 kg/ha for all the treatments. It is however recommended that acidification of Thundulu phosphate rock with sulphuric acid should be examined and the cost effectiveness as a P source studied

as an alternative to the unsatisfactory addition of untreated rock phosphate. Organic residues (maize stover and cattle manure) must be applied in acid solid at the rate of 3 t/ha per year to reduce the Al toxicity. There is need for longer term studies using the same treatments

Citation: Nyirongo J.C.V.B, (2001). Soil fertility studies with compost and phosphate rock amendments at Lunyangwa and Bembeke Research Stations, MSc. Thesis, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

A11.21 Adoption of Soil Fertility Improvement technologies among smallholder farmers in Southern Malawi

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Land degradation and soil erosion are significant environmental problems affecting agricultural productivity and livelihood in Malawi. A number of soil fertility improvement technologies are being promoted by the Ministry of Agriculture and non-governmental organization, in order to improve agricultural productivity and food security. The thesis examines farmer's perception of the current level of soil fertility and factors effecting farmers use of different soil fertility improvement technologies. The study was carried in Machinga Agriculture Development Division, Machinga and Zomba districts. Household questionnaire, key informants interview and literature review were used as tools for data collection. A total of 97 households were interviewed. About 73% of farmers perceive that the current level of soil fertility as low and 62%, perceived that soil fertility will continue to decline. The overall reason for using different soil fertility improvement technology is to improve crop yield for household consumption and cash income. Farmers use inorganic and organic fertilizers for soil fertility improvement. The majority of farmers (83%) prefer to use inorganic fertilizers. High price was mentioned as the main factor limiting use of inorganic fertilizer. Therefore, percentage farmer's use of inorganic fertilizer increased with increase in income level. Labor demand limits farmer's use of agroforestry practices. Increase in the number of farmers inheriting land will reduce the use of agro forestry technologies ($p \leq 0.01$). Most female headed families (55%) use compost manure. Use of compost manure decreased with increase in off farm income ($p \leq 0.01$). Livestock manure use is affected by livestock holding sizes. Use of livestock manure increased with increase in livestock holding size ($p \leq 0.01$). Farmer participation in farmer groups also increased use of compost and livestock manure, $p \leq 0.01$ and $p \leq 0.05$, respectively. About 39% of farmers combine organic and inorganic fertilizer for soil fertility improvement. Farmer use of different soil fertility improvement technologies is affected by technology characteristics and different socio- economic factors.

Citation: Chinangwa L.R (2006). Adoption of Soil Fertility Improvement technologies among smallholder farmers in Southern Malawi, MSc Thesis. Norwegian University of Life Sciences. Department of International Environment and Development Studies, Norway.

BACHELOR OF SCIENCE RESEARCH

B11.1 The effect of some elite soybean lines and manure application on yield, yield components and the incidence of *Alectra vogelii*, a parasitic weed

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An experiment was conducted at Bunda College of Agriculture Student Farm in the 2013/14 growing season to determine the effect of some elite soybean lines and manure application on soybean yield, yield components and the incidence of *Alectra vogelii*, a parasitic weed. A 2 x 4 factorial experiment in a Randomized Complete Block Design (RCBD) was used. Four elite soybean lines were used; TG x 1835-10E, TG x 1987- 10F, TG x 1830-20E and TG x 1987-62F and two cattle manure rates were used ; 0 tones/ hectare and 5 tons/ hectare. The results showed that there was no significant ($P=0.05$) difference among the four elite lines on grain yield, pods/ plant, plant height, plant biomass and branches per plant except on 100 seed weight. The results also showed that, cattle manure had a significant effect ($P=0.05$) on yield. Manure treated plots had an average yield of 3044kg/ha compared to 2215kg/ha from unfertilized plots. On growth parameters, manure had also an effect on plant height, pods/ plant, branches per plant, plant biomass and 100 seed weight. The experiment did not show an interaction effect of the two factors on both yield and yield components. However, the *A. vogelii* did not show up in the field despite that the neighbouring legume fields (ground nuts and cowpeas) had plenty of it. Therefore it is recommended that farmers should be encouraged the use of manure in soybean production for high yield.

Citation: L.M Kamanga (2015). The effect of some elite soybean lines and manure application on yield, yield components and the incidence of *Alectra vogelii*, a parasitic weed, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi

B11.2 Effect of cutting height on seed and dry matter production of different multipurpose tree species

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The forage, wood and total biomass and seed production were assessed for three cutting height (25, 50 and 75 cm). the trial was conducted at Bunda College of Agriculture Research Farm. It was run for two years split in 2 phases; first season for seed production and second season for dry matter production (forage, wood and total biomass). The species that were evaluated are *Acacia angustissima* OFI65/92, *Calliandra colathyrus* OFI12/91, *Leucaena tricandra* OFI53/88, *Acacia angustissima* OFI68/92, *Leucaena diversifolia* OFI35/88, *Leucaena palida* OFI137/94, *Acacia angustissima* OFI70/93 and *Leucaena esculenta* OFI52/87. Cutting height generally influenced seed and dry matter production. Greater cutting height ensured greater shoot development as observed at 75 cm than the lower heights ($P < 0.001$). consequently the greater the shoot development influences the overall dry matter yield as well as seed yield. Accession *Acacia angustissima* OFI70/93 yielded more dry matter than all other accessions. Lowest dry matter yield was realized from *Leucaena diversifolia* OFI35/88. Seed size was inversely related with cutting height. High cutting height produced low weight of 1000 seeds at $P < 0.05$, but overall seed yield increased with increase in cutting height. Number of branches increased with increase in cutting height at $P < 0.05$ and *Calliandra calothyrsus* OFI 12/91 gave highest number of branches as compared to other accessions.

Citation: Pungulani L.L M (1999), Effect of cutting height on seed and dry matter production of different multipurpose tree specie, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.3 Nitrogen immobilization and mineralization during the initial decomposition of groundnut shells, maize residues and pigeonpea leaves

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The experiment was carried out in the Soil Science Laboratory at Bunda College of Agriculture in the year 2003 (March to June). This was done to compare the effect of crop residues with different chemical composition on mineralization and immobilization of nitrogen during the initial 16 weeks of decomposition. In addition there was need to study the combined influence of different soil with different crop residues on mineralization and immobilization. Here differen crop residues (maize, pigeonpea and groundnuts) and two different types of soil (sandy clay loam and Sandy loam) were used. The incubation was done at room temperature in the dark and the experiment was replicated three times. The quantities of extractable ammonium and nitrated released to the soil to which the crop residues had been added were determined after 7, 14, 28, 56 and 112 days and were related to different chemical composition and different soil types. The ammonium and nitrate levels upon residues application ($P < 0.05$) have shown that there was significant difference in mineralization and immobilization processes in all the three crop residues. The mineralization was being higher upon application of groundnut residues followed by pigeonpeas and last the maize residues. This suggests that groundnuts residues have the capacity to release nitrogen in form of ammonium and nitrate at the high rate. On the other hand, maize residues enhance immobilization of nitrogen more than pigeonpeas leaves and groundnut residues. Regarding the interaction of soil type and crop residues, it has been observed that sandy loam soil combined with groundnuts residues gave a higher mineralization. On the other hand, immobilization process was high in the sandy clay loam combined with maize residues. Moderate rates of slight mineralization and immobilization were observed in the combination of different soil types and pigeon peas residues. Slight increase in the soil pH was obtained with time of incubation especially in the combination of groundnuts residues with dandy loam soil.

Citation: Elifas B, (2004). Nitrogen immobilization and mineralization during the initial decomposition of groundnut shells, maize residues and pigeonpea leaves, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.4 Effects of different growth media and fertilizer types on the growth and development of tobacco (*Nicotinana tobacum* L) in a floating tray system

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A study on the effect of different growth media and fertilizer types was carried out at Bunda College of Agriculture Crop Science Student research farm in a screen house during the 2006/07 growing season. Three fertilizer types: 20:10:20 (imported). S-Mixture (6:18:6) and 20:11:5 (locally found) and three media types: compost pine bark

(imported), groundnut shells and used coal pebbles (locally found) were laid out in Split-plot design with fertilizer types as type as the main plot factors and media types as sub plot factors. All data was collected by eight week, just before the seedlings could be transplanted. The results showed that seedlings raised using compost pine bark produced significantly better performance than those grown on groundnut shells and used coal pebbles. Groundnut shells were the second superior growth media after compost pine bark. The effect of the three fertilizer types were similar, showed non-significant difference on the seedlings dry mass, leaf number, root length, root volume, seedling height and stem diameter. There was no interaction effect between the fertilizer types and growth media

Citation: Sibande L. A.G.O, (2008). Effects of different growth media and fertilizer types on the growth and development of tobacco (*Nicotinana tobacum* L) in a floating tray system, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.5 Effects of nitrogen levels and watering frequencies at flowering stage on flowering, pod setting and seed yield in cat's whiskers (*Cleome gynandra*)

G. K A Sibande; University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

A screen house experiment on the effect of nitrogen levels and watering frequencies at flowering stage on flowering, pod setting and seed yield in cat's whiskers (*Cleome gynandra*) 2001/ 2002 season) was conducted at Bunda College of Agriculture. The experiment had two factorial treatments with a Completely Randomized Design (CRD). The first factor was three watering frequencies at flowering stage designated as daily watering (W1), watering every 4 days (W2), watering every 8 days (W3). The second factors was he levels of nitrogen as 0 kg N/ha (N1), 25 kg N/ha (N2) and 50 kg N/ha (N3). The interaction between watering frequencies and nitrogen levels significantly affected flowering and pod setting ($P=0.05$) where the highest number of flowers were obtained from W2N3 (75 flowers per plant) and the highest number of pods were obtained from W1N2 (8 pods per plant). However, none of the treatments significantly affected seed yield (g/pant) and seed size in cat's whiskers. This may suggest that manipulation of moisture, N nutrition or their interaction has no effect on the seed yield and seed quality in the cat's whiskers. It is recommended that the experiment be repeated in the field so as to suggest the treatments to real field conditions and where large enough sample can be obtained. Split application of N is suggested to ensure its availability during the pod filling.

Citation: Sibande GKA (2002). Effects of nitrogen levels and watering frequencies at flowering stage on flowering, pod setting and seed yield in cat's whiskers (*Cleome gynandra*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.6 Maize response to residual nitrogen contribution from legumes

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An experiment to investigate the response of maize to residual nitrogen from forage legumes was carried at Bunda College Students' Research Farm during the 1993/94 cropping season. the experimental site was previously under three forage legumes namely: Archer (*Macroptillium axillare*), Centrosema (*Centrosema pubescens*) and Siratro (*Macroptillium atropurpureum*) for three growing seasons (1990/01, 1991/92 and 1992/93). Twelve treatment combinations of four N-levels (0, 20, 40 and 80 kg N/ha) and three forage legumes (Archer, Centrosema and Siratro) were factorially arranged in a Randomized Completely Block Design (RCBD) with three replicates. The gross plot was eight metres by eight metres with ridges spaced at 91 cm apart. The net plot size was two middle ridges discarding two planting stations from either end of the ridges to serve as borders. The responses of plant height, cob height and cob weight to nitrogen leveled off when the amount of nitrogen exceeded the 40 kg N/ha level. However, a further increase in the nitrogen to 80 kg N/ha level only yielded small percentage, suggesting that there was no beneficial nitrogen effects beyond the 40 kg N/ha level. There was significant ($P<0.05$) effect of the forage legume on the plant height and percent nitrogen in grain. There was no significant difference in the rest of the variables under study attributed to either the inorganic nitrogen fertilizer or the forage legumes effects. The possible reason to this would be because of the inadequate rainfall which was poorly distributed. Poorly rainfall distribution may have led to poor utilization of the N by the maize variety. The study suggests that the intercropping of the forage legumes into the arable rotation program would reduce the production cost but would not eliminate completely the need for supplementary nitrogen for successful maize production.

Citation: Bakuwa J, (1995). Maize response to residual nitrogen contribution from legumes, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.7 Maize yield response to nitrogen and phosphorus of field previously under *Leucaena* and *Sesbania* fallows

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Improved fallows are known to improve the soil fertility levels through fixation of nitrogen from the atmosphere and nutrient recycling (some have deep systems which assist them capture nutrients from the deeper layers of the soil). These trees also trap moisture from the deep layer of the soil. When they have grown to a considerable height they are pruned so that their leaves upon decomposition in the soil they release nutrients in the soil for crop growth. These trees also improve soil structure, so this offers a good environment for the growth of the crop plants as infiltration of water and mass flow of water in the soil is enhanced. *Sesbania sesban* and *Leucaena leucocephala* were the tree species that were used in the fallows. The overall objective of this study was to investigate the maize yield response to nitrogen and phosphorus in the field previously under *Leucaena* and *Sesbania* fallows. The specific objectives were; To determine the response of maize to nitrogen and phosphorus levels on the field previously under *Leucaena* and *Sesbania* fallows; To compare the effect of *Leucaena* and *Sesbania* on maize yield. The treatments of this experiment were laid out in a Randomized Completely Block Design (RCBD). There were three replicates per treatment. The results indicated significant increases ($P < 0.001$) in the response of maize yield to nitrogen and phosphorus in addition to *Leucaena* and *Sesbania* fallows. The highest maize grain yield (5582 kg/ha) was obtained in the treatment four (46 kg N & 42 P/ha). No significant differences in the soil content attributed to the two tree species ($P > 0.05$). The result from this experiment indicated that increase in nitrogen and phosphorus resulted in increase in maize grain yield. This is observed from the mean of the grain yields. The control, 11.5 kgN & 10.5 kg P/ha, 23 kg N & 21 kg P/ha and 46 kg N & 42 kg P/ha yielded 3113 kg/ha, 4677 kg/ha, 5031 kg/ha and 5582 kg/ha of grain maize yield respectively. The tree species (*Leucaena* and *Sesbania*) showed that their effect on grain maize yield was the same across the nitrogen or phosphorus treatment combinations. However, the statistically differences were observed from the control treatment (3113 kg/ha, the 11.5 kg N & 10.5 kg P/ha treatment (4677 kg/ha). This means that little supplementation of the fertilizer on the tree fallows can lead to high grain yield in maize. This result has economic implication in the sense that smallholder farmer can save cost on fertilizers.

Citation: Dambuleni R.K, (2005). Maize yield response to nitrogen and phosphorus of field previously under *Leucaena* and *Sesbania* fallows, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.8 The response of grain *Amaranthus* species to nitrogen fertilizer and irrigation regimes

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The study on the response of grain *amaranthus* species under irrigation was carried out at Bvumbwe Agriculture Research Station from July to December, 2001. Three *amaranthus* species (*A. hypochondriacus*, *A. montegazzianus* and *A. cruentus*) were subjected to three nitrogen fertilizer application rate (0, 25 and 50 kg N/ha) at three irrigation regimes) twice per week, once per week and once per fortnight). Nitrogen application rate of 50 kg N/ha gave the highest yield of grain (2.93 t/ha) while 25 kg N/ha and zero N application gave 2.28 t/ha and 1.82 t/ha grain yield respectively. However, 25 kg N application gave the highest and better leaf quality. Irrigation of once per fortnight was optimum for grain production. This watering frequency gave 2.49 t/ha grain as compared to 2.48 t/ha and 2.05 t/ha grain yield from once per week and twice per week irrigation intervals. For leaf, once per week irrigation was better in order to maintain the succulence of the leaves. No significant differences were observed in the yields of the three biotypes which gave an average of 2.34 t/ha grain. Any one of the varieties can therefore be recommended for grain and leaf production under irrigation conditions.

Citation: Banda S.I.M, (2002). The response of grain *Amaranthus* species to nitrogen fertilizer and irrigation regimes, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.9 Effects of lime and phosphorus on growth and some nutrients uptake by soybean plants

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A greenhouse experiment was conducted to study the effect of lime and phosphorus on soybeans growth and its uptake of nitrogen, phosphorus, calcium and magnesium. Acid soil from Mzuzu was used. Three levels of lime (5, 10 and 15g/2 kg soil) and three phosphorus levels (0.5, 1 and 1.5g/2kg soil) were applied. Results showed that high levels of lime cause a decrease in plant height, number of leaves and dry matter yield. An increase in dry matter was observed with phosphorus additions at each level of lime additions. There is a slight decrease in nitrogen uptake with increasing phosphorus and lime and phosphorus application. On the other hand, phosphorus uptake has increased with phosphorus application. Available in the soil after harvesting and therefore higher amounts of phosphorus uptake by soybean plants was observed in the treatment of 10g/pot lime and 1.5g/pot potassium phosphates.

The slight increase in the soil pH after harvesting was due to short time of reactions with soil acidity. It is recommended to repeat such experiments using different lime materials and different sources of phosphate fertilizers and also different soil types in order to give better advice to farmers and obtain high yields.

Citation: Ngwira S, (2004). Effects of lime and phosphorus on growth and some nutrients uptake by soybean plants, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.10 Effects of nitrogen sources on soil fertility and maize yield

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A study was conducted at Bunda College Student Research Farm in the 2000/01 growing season to investigate to the effect of nitrogen sources on soil fertility and maize yield. M.H 18 hybrid maize variety was planted in 18 plots each measuring 10m by 10m where nitrogen sources were applied. The nitrogen sources were referred to as treatments and these were: 0 kg N, 40 kg N, Tephrosia vogelii, Tithonia diversifolia and Sesbania sesban. A field lay out was in a Randomized Complete Block Design (RCBD) and data was analyzed using Gen Stat 2000 and means were separated using Least Square Difference. Results showed that maize yields were influenced by nitrogen application such that there were high significant differences in the grain yield of maize at $P < 0.001$. Sesbania treatment had the highest grain yield of 963 kg/ha amongst the tree species used while Tephrosia treatment produced the least grain yield of 643 kg/ha. In terms of stover yield; core weight cob height and length, Sesbania sesban also had the greatest influence as compared to the rest of t species of trees. In terms of biomass production, it was also found that Sesbania produced the highest biomass of both wood and leaf. i.e. 3047 kg/ha and 2621 kg/ha, respectively. The lowest biomass was from Tephrosia vogelii having the wood biomass of 1852 kg/ha and leaf biomass of 2000kg/ha. In addition, it was observed that the best quality of biomass was produced from Sesbania sesban with 96.8 kg N/ha. However, there were significant different amongst species used in terms of nitrogen content and leaf biomass at ($P < 0.05$). From this study it was concluded that relay cropping with Sesbania sesban provided the best source of nitrogen and gave the best biomass production and maize yield.

Citation: Thawani EE (2002). Effects of nitrogen sources on soil fertility and maize yield, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.11 The effects of nitrogen fertilizers on the growth of Coriander (Coriandrum sativum)

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A screen house experiment on the effect of nitrogen fertilizers on the growth of coriander (*Coriandrum sativum*) was conducted at Bunda College Student and Staff Research Farm during the 2002/03 growing season. The objective of the project was to study the effect of nitrogen fertilizers at different levels of application on coriander growth. The experiment was a two factorial laid in a Completely Randomized Design (CRD). The first factor was the form of nitrogen fertilizers designated as N1 (ammonium phosphate), N2 (ammonium nitrate) and N3 (sodium nitrate). The second factor was the levels of nitrogen fertilizers denoted as L1 (20 kg/ha), L2 (30 kg/ha) and L3 (40 kg/ha). The collected data was analyzed using Gen Stat computer package, 5th Edition and means were separated using the Least Significant Difference (LSD). The nitrogen fertilizers and levels significantly affected seed yield, leaf length and dry matter yield at $P = 0.05$. There was a correlation between the nitrogen levels and yield. For all the three fertilizers, seed yield increased as nitrogen rate was increasing. Ammonium sulphate gave highest yield followed by ammonium nitrate and then sodium nitrate. Nitrogen fertilizers supported coriander plants to effectively absorb other nutrients such as phosphorus and potassium. Phosphorus uptake was in the order $\text{NaNO}_3 > \text{NH}_4\text{NO}_3 > (\text{NH}_4)_2\text{SO}_4$. It is recommended that the experiment should be repeated in the field so as to expose the treatment to real environment field conditions. It is also recommended that research be done on higher nitrogen levels in order to determine the optimum level that can be recommended to farmers to obtain the optimum yield.

Citation: Chigwenembe SS (2003). The effects of nitrogen fertilizers on the growth of Coriander (*Coriandrum sativum*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.12 Intercropping of sunflower (Helianthus annus) with common food legume: effect on food and disease incidence

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In the growing season 1993/94, a field experiment was conducted at Bunda College of Agriculture Students' Research Farm on intercropping of sunflower (*Helianthus annus*) var. Pan 7232, and Var. Sudan; Soybean (*Glycine max*) var. Ocepara 4 and Pigeonpea (*Cajanus cajan*) var. ICP 9145 to assess the performance of sunflower

when intercropped with the legumes in terms of grain that was significant differences ($P>0.05$) in grain yield of sunflower and cowpeas between pure stands and intercrops. In soybean and pigeonpea stands, yield didn't differ statistically at 5 % alpha level of significance. Three important diseases attacked sunflower namely: Alternaria leaf spot (*Alternaria helianthi*), Septoria leaf spot (*Septoria helianthi*) and sunflower yellow Blotch Virus (SYB). In cowpea *Ascochyta* blight (*Ascochyta phaseolum*) was the only disease that seriously attacked the crop. But there were no serious disease attacks in soybean and pigeon pea crops. All the diseases showed high intensities in the pure stand and were statistically different ($P>0.05$) from the intensities in the intercrops and all of the correlated negatively with the grain yields. In cowpea, Folliage beetles (*Ootheca* spp.) aphids (*Aphis craccivora*) were the most important pests that attacked the crop. no serious pest attacks were noted in other crops.

Citation: Mbalafana S.H, (1995). Intercropping of sunflower (*Helianthus annuus*) with common food legume: effect on food and disease incidence, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.13 The development and productivity of air potato under different cultural practices

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Research was carried out at Bunda College of Agriculture Students Research Farm during the 2003/2004 growing season to assess/ evaluate the response of air potato to different planting systems and Nitrogen fertilizer levels. The treatments planting systems (Mound and Flat) CAN, N-fertilizer levels (0 and 20.5g), were tested in randomized completely block design with four replicates. Data was collected on tuber dry matter weight (kg), shoots dry matter weight (kg) and plant length (cm) at harvesting period. Analysis of Variance was performed on tuber dry matter, shoot dry matter and plant length (cm). Statistically, the interactions between the planting systems and N-fertilizer levels on the means for tubers, shoots and plant length were significant at 5 % level of significance. However, there was also significant differences ($P<0.05$) in yield performance between mound system of planting with application of nitrogen versus flat system of planting without nitrogen fertilizer application. So the results showed that mound planting system with fertilizer application are the better cultural practices which can give highest yield good field conditions.

Citation: Kanyika BS (2005). The development and productivity of air potato under different cultural practices, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.14 Response of Livingstone potato (*Plectranthus esculentus*) a Malawian collection to nitrogen fertilizer application

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The growth and yield potentials of Livingstone potato genotypes (*Plectranthus esculentus*) and their response to inorganic fertilizers were assessed. The experiment was carried out at Bunda College of Agriculture Students Research Farm during the 2002/03 cropping season. The experiment was laid out in split plot design, where the main plot treatments were four genotypes namely; Bembeke 1, Tsangano 15, Chilobwe 1 and Chilobwe 2. Subplots treatment were three urea inorganic fertilizer levels, 0 kg/ha, 50 kg/ha and 100kg/ha. Results showed that the genotypes were not significantly different in yield, diameter, number of branches and number of tubers and harvest index, $P=0.05$. Significant differences appeared in height only where Bembeke 1 and Chilobwe 1 and 2 appear to be tall plants and Tsangano 15 appears to be dwarfed. Fertilizer levels showed significant difference ($P<0.001$, in yield and diameter, number of branches and number of tubers as well as harvest index. Increase in fertilizer resulted into increase in all the parameter under study. All these parameters were not significantly different $P=0.05$ in genotype x fertilizer combinations. The yield was increasing with increase in number of branches, number of tubers, plant height, as well as diameter of the tubers. This is according to the correlations which were done.

Citation: Mambulasa D (2004). Response of Livingstone potato (*Plectranthus esculentus*) a Malawian collection to nitrogen fertilizer application, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.15 Response of hybrid maize variety to different levels of nitrogen, phosphorus and potassium

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A representative soil sample for this study was taken from a field at Bunda College where no potassium fertilizer has been applied for three successive seasons, and subjected to laboratory and greenhouse investigations. Laboratory investigations indicated that the soil was a clay loam, acidic in its reaction, containing 4.83 $\mu\text{g/g}$ Mehlich 3-extractable P, 0.011 $\mu\text{g/g}$ Mehlich 3- extractable K, 0.18 $\mu\text{g/g}$ Mehlich 3-extractable Mg; and 0.93 $\mu\text{g/g}$

exchangeable Ca, 2.06 percent organic matter content; and 0.21 percent total N. Statistical analysis showed that the differences in foliar N contents due to treatments are statistically significant and that differences in foliar N contents were highest in the test crop obtained from the pot to which 100, 50 and 0 mg P had been added. The analysis of variance (ANOVA) showed that differences in the biomass of the test crop due to nitrogen, phosphorus and potassium treatments effects were statistically significant. The highest mean biomass was obtained from the crop obtained from the pot that received 100 mg N, 50 mg P and 50 mg K per culture. When yield was regressed on K treatments effects, the following regression equation was obtained; $y=0.023x+9.292$ and statistical analysis indicated that about 78% of the variation in the biomass was attributable to K treatment effects. When K contents were regressed on K treatments effects, the regression equation obtained was: $y=0.172-0.986$, and statistical analysis showed that about 72% of the total variation in foliar contents was attributable to K treatments.

Citation: Kapenda P (2010). Response of hybrid maize variety to different levels of nitrogen, phosphorus and potassium, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.16 Evaluation of *Tithonia diversifolia*, *Gliricidia sepium* and *Leucaena esculenta* biomasses as possible nutrient sources for onion

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A research was conducted to evaluate the effect of *Tithonia diversifolia*, *Gliricidia sepium* and *Leucaena esculenta* on growth, yield and quality of onion (*Allium cepa* L.). The research was sited at Bunda College of Agriculture Department of Crop Sciences Students Research Farm during the 2013/2014 rainfed growing season. eight treatments consisting of the three biomass nutrient sources, inorganic fertilizer, fertilizer-biomass combinations and a control were laid out in three replications, each delivering 114 kg N/ha except the control. Biomasses were incorporated in the soil two weeks before planting of seedlings at the rate of 22 t/ha, 11.6 t/ha and 14 t/ha for *Tithonia diversifolia*, *Gliricidia sepium* and *Leucaena esculenta* respectively. The application rate was based on the nitrogen requirement of the onion. *Gliricidia sepium* in combination with inorganic fertilizer produced highest fresh bulb yield among all the biomasses with 18.8 and 165.4% increase over inorganic fertilizer and the control, respectively. However, biomass as a sole source of nutrients performed poorly compared to *Tithonia diversifolia* and *Leucaena esculenta* biomasses. *Tithonia diversifolia* and *Leucaena esculenta* when applied either alone or in combination with inorganic fertilizers gave comparable yields to full rate of inorganic fertilizers. The yield responses were attributed to timely nutrient availability influenced by the rate of decomposition of the biomasses. Thus, nutrients availability in the early onion growth stage promoted vegetative growth, plant height and number of leaves, which were key determinants of onion bulb size and weight. *Gliricidia sepium* and *Leucaena esculenta* biomasses reduced the quality of onions by increasing neck thickness, which were a result of low phosphorus concentration in these biomasses. In view of these results, smallholder farmers are recommended to use *Tithonia diversifolia*, *Gliricidia sepium* and *Leucaena esculenta* biomasses for onion production. However, *Leucaena* and *Gliricidia* should be combined with inorganic fertilizers for optimal onion yield and quality.

Citation: Mvona J, (2014). Evaluation of *Tithonia diversifolia*, *Gliricidia sepium* and *Leucaena esculenta* biomasses as possible nutrient sources for onion, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.17 Maize response to fertilizer application rates and placement method of pigeonpeas residues

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Tree legumes such as pigeon peas (*Cajanus cajan*) are good candidates for agroforestry. In additions to their symbiotic relationship with *Rhizobium* spp. which fix nitrogen into the soil, pigeon peas also acts as an important source of food. Smallholders use the stems as source of fuel wood and the leaves unfortunately are wasted and only those leaves that drop onto the ground are responsible for nutrient recycling. A study was conducted to find out the best option of utilizing the leaf litter in a rotation system of pigeon peas with maize. The leaves were placed on the surface in a zero tillage farming system and in other plots they were incorporated into the soil. The trial was conducted at Bunda Crop Science Department Students Research Farm during the 2007/08 growing season. The results showed that the interaction of residues and fertilizer rate had no significant effect on yield ($P>0.01$) but had an effect on the number of kernels per ear ($P<0.01$) and cob length ($P<0.01$) at significant level of 0.05. The results also showed that there was a significant effect in yield when different rates of fertilizer were used $P<0.007$ and that the biomass was highly significant ($P<0.01$) significant at a level of 0.05. Results also showed that placement method of pigeon pea residues had an effect on yield of maize. Placement method of residues on yield was significant ($P<0.042$) and biomass was also significant ($P<0.015$).

Citation: Sanga FD (2009). Maize response to fertilizer application rates and placement method of pigeonpeas residues, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.18 Assessment of biological nitrogen fixation and yields in some elite common beans (*Phaseolus vulgaris*) varieties as affected by different rates of phosphorus fertilizers

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A field experiment was conducted at Lilongwe University of Agriculture and Natural Resource, Bunda College Campus under the Department of Crops and Soil Science at Students Research Farm during the 2013/2014 growing season to assess nodulation, biological nitrogen fixation and yield of some elite common bean varieties at different rates of phosphorus fertilizer. The treatments comprised three levels of phosphorus (0, 20, 40 kg/ha) and three varieties of common beans namely BCB1, BCB2 and BCB3. Maize variety (SC 403) was used in the experiment as a control to determine the quantity of nitrogen fixed biologically. The treatments were laid in a randomized completely block design (RCBD) replicated three times in a factorial arrangement. The amounts of biologically fixed nitrogen were quantified using modified nitrogen different methods. The results showed significant differences ($P < 0.05$) on nodulation, BNF, and grain yield of three common bean variety due to fertilizer and variety effect. Grain yield increased by 51 and 49% for BCD2 and BCD3 varieties respectively over BCD1 which produced the least grain yield. No significant effect in grain yield for varieties BCD2 and BCD3 were observed. Phosphorus significantly influenced nodulation, BNF and yield ($P < 0.05$) with N fixed increased with increase in P application rate i.e. 24.4, 38 and 53 kg/ha N at application rate of 0, 20 and 40 kg P/ha respectively. Nodulation and grain yield were also observed to be increased with increase in application rate of phosphorus fertilizer. The results of the experiment also showed significant differences ($P < 0.05$) on the varieties on nodulation, BNF, and grain yield with BCD2 and BCD3 recording the highest N fixed respectively while BCD1 had registered least amount of grain yield, nodulation and biologically fixed nitrogen. From this study it was concluded that nodulation, BNF and grain yield were influenced by P application and variety effect whereby increase in P application rates increased the parameters consistently. It can therefore be recommended that similar studies should be repeated in sited with different soil types.

Citation: Fabiano YM (2015). Assessment of biological nitrogen fixation and yields in some elite common beans (*Phaseolus vulgaris*) varieties as affected by different rates of phosphorus fertilizers, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi,

B11.19 The residual effect of fertilized *Tephrosia vogelii*, *Mucuna pruriens*, *Cajanus cajan* and *Zea mays* with different levels of phosphorus on the performance of maize growth in the subsequent season

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High fertilizer costs and declining soil fertility are among the key factors contributing to the low crop yield in Malawi. The contribution of three legumes grown in a short fallow, and application of different levels of P and performance of succeeding maize (*Zea mays* MH18) was studied in an experiment at Bunda College of Agriculture in the growing season of 2000/01. The treatments included 0, 20 and 40 kg P/ha, three green legumes: *Tephrosia vogelii*, *Mucuna pruriens*, *Cajanus cajan* and maize grown in 1999/00 growing season followed by maize in 2000/01 growing season. The crop residues were incorporated in the soil during the ridge preparation and the maize crop was supplied with 50 kg N/ha. The design was a split plot design arranged in a randomized completely block design replicated three times. Results showed improved N and P soil status following legumes, *Mucuna pruriens* giving the highest N at 20 kg P/ha followed by *Cajanus cajan* at the same fertilizer level. *Tephrosia vogelii* contributed the available phosphorus at 20 kg P/ha. Grain yield in maize succeeding legumes was higher than maize succeeding maize with *Tephrosia vogelii* giving the highest grain yield (8019 kg/ha) on average at 20 kg P/ha followed by *Mucuna pruriens* (1883 kg/ha). However, the results were not significant at 5% level of confidence. The study had demonstrated that the use of legumes supplied with Phosphorus fertilizer in rotation with maize is a viable option and advantageous over maize monocropping.

Citation: Khonje KLJ (2002). The residual effect of fertilized *Tephrosia vogelii*, *Mucuna pruriens*, *Cajanus cajan* and *Zea mays* with different levels of phosphorus on the performance of maize growth in the subsequent season, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.20 Response of *Plectranthus esculentus* (Livingstone potato) to inorganic fertilizer application

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An experiment on the response of *Plectranthus esculentus* to inorganic fertilizer application was carried at Bunda College of Agriculture, Crops and Soil Sciences Research Farm during the 2001/2002 cropping season. the experiment was laid out in a split plot design (SPD), where the main plot treatments were two *Plectranthus esculentus* genotypes, Tsangano15 and Chilobwe 1 while the subplot treatments were four Calcium Ammonium

Nitrate (CAN) inorganic fertilizer levels (0kg/ha, 50kg/ha, 100kg/ha and 150kg/ha). The treatments were replicate three times. In general tuber yields were low than expected due to low plant population in the field and low rainfall amount. Analysis of the results showed that inorganic fertilizers levels were significantly different at $P=0.05$ in tuber yield with 150 kg/ha producing highest tuber yield of 772 kg/ha. The mean tuber yield between genotypes were significantly different at $P=0.05$. Tsangano 15 produced higher tuber yield of 847 kg/ha than Chilobwe levels was significantly different ($P=0.05$) in the tuber yield, length and diameter of tubers, number of tubers/plant and weight of dry stems and branches. The weight of dry stems and branches, diameter of tubers and length of tubers were significantly different between the genotypes and also among the different inorganic fertilizer levels applied while number of tubers per plant was not significantly different at $P=0.05$ in the genotypes and fertilizer levels. The highest weight of dry stems and branches length of tubers, number of tuber/plant, plant height and diameter of tubers in *Plectranthus esculentus* genotypes did not necessarily mean higher tuber yield. The tuber yield, number of tubers/plant, weight of dry stems and branches, diameter and length of tubers did not necessarily increase with increase in inorganic fertilizer levels.

Citation: Kipandula J. L, (2002). Response of *Plectranthus esculentus* (Livingstone potato) to inorganic fertilizer application, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.21 Effects of madeya and fertilizer combination on maize growth and yield

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An increasing number of smallholders are claiming that a mixture of madeya with a small amount of inorganic fertilizer especially urea give good yield of maize. No study has been done to confirm this claim. Hence this study was conducted to evaluate the claim. The study conducted at Bunda College Crop and Soil Science Student Research Farm during the 2013/2014 growing season. The following treatments were used; T1 200kg/ha madeya plus 70kg urea, T2 400kg/ha madeya plus 70kg urea, T3 200kg/ha madeya only and T4 70kg urea only. The results at $p>0.05$ showed that applying 70kg/ha urea only (T4) produced the highest maize yield (4148kg/ha). However, this yield was statistically similar to applying 400kg/ha madeya plus 70kg/ha urea which produced maize yield of 3333kg/ha. Applying madeya only (200kg/ha) produced the lowest maize yield of 1222kg/ha. From the results it can be concluded that applying madeya mixed with urea is just the same as applying urea only.

Citation: Mtambalika C (2015). Effects of madeya and fertilizer combination on maize growth and yield, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.22 Estimation of biomass production and litter quality of Sesbania sesban, Tephrosia vogelii, and Tithonia diversifolia under a short term improved fallow technology

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In most Malawian soils, soil fertility has been declining because nearly continuous maize (*Zea mays*) cultivation with little or no nutrient inputs. In trying to combat this problem, a study was carried out at Bunda College during the 1999/2000 cropping season to determine the effect of a short term improved fallow technology on biomass production and litter quality of *Sesbania sesban*, *Tephrosia vogelii*, and *Tithonia diversifolia*. The experiment was laid out as randomized completely block design with three replicates per treatment. Results indicated that high leafy (2233kg/ha) and wood (10989 kg/ha) biomass could be obtained from *Sesbania sesban* which happened also to have litter high in nitrogen content (4.48%). *Tephrosia vogelii* was superior in litter accumulation (1637 kg/ha) and had high phosphorus content (0.59%). *Tithonia diversifolia* moderate in terms of both biomass production and litter quality. From these results it is concluded that a farmer would benefit more from *Tithonia diversifolia* than from *Sesbania sesban* and *Tephrosia vogelii* in terms of contribution of litter and phosphorus to the soil, which would be in turn mitigate the soil fertility problem. However, in terms of nitrogen contribution *Sesbania sesban* appeared to have an advantage over the other two species. In terms of biomass production, it would appear from this study that *Sesbania sesban* would contribute the largest amount to the soil.

Citation: Kopa JTJ (2001). Estimation of biomass production and litter quality of *Sesbania sesban*, *Tephrosia vogelii*, and *Tithonia diversifolia* under a short term improved fallow technology, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.23 The influence of hardening off age, fertilizer type and time of application during rooting phase of vegetatively propagated material raised from plucking shoots in tea (*Camellia sinensis*)

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Nursery trials for Tea (*Camellia sinensis*) were conducted at Mimosa station of Tea Research Foundation (Central Africa) to establish optimum ages for hardening-off and to identify types of fertilizers and find out time of basal application for vegetatively propagated materials raised from plucking shoots in the nursery. Urea and Callmag +B were evaluated as an alternative to Sulphate of Ammonia. Time of hardening off (age) had a statistically significant effect ($P \leq 0.05$) on the development of shoots during the rooting phase. The age of 14 was found to be the optimum age for basal fertilizer application. There was no significant difference between the three fertilizer type namely: Urea, Sulphate of Ammonia and Call mag +B. Thus Urea and Call mag+B could be substituted for Sulphate of Ammonia with no adverse effects on the performance of materials from plucking shoots during their rooting phase.

Citation: Nkhoma S. P. M, (2003). The influence of hardening off age, fertilizer type and time of application during rooting phase of vegetatively propagated material raised from plucking shoots in tea (*Camellia sinensis*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.24 The effect of phosphorus on the growth of Bambara groundnuts (*Vigna subterranea*), groundnuts (*Arachis hypogaeae*) and soybean (*Glycine max*)

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Research was conducted at Bunda College of Agriculture Student's Research Farm during the 1999/00 growing with the aim of finding out the advantage of applied P fertilizer to legume growth, N fixation and how much of it would be available for the subsequent maize crop. The legumes grown were the Bambara groundnuts (*Vigna subterranea*), groundnuts (*Arachis hypogaeae*) and soybean (*Glycine max*) and maize was grown as a control. The experiment was a Randomized Completely Block Design evaluated in a split plot. Four plots were grown to Bambara groundnuts, groundnuts and soybeans and maize with three replicates and three levels of inorganic fertilizer (23:21:0 +4S) as source of phosphorus were used, 0, 20 and 40 kg/ha were applied to each plot. At 50% flowering, nodules were counted and weighed from each legume. Nitrogen in roots and shoots was determined at 50% flowering while P and S were determined at zero time and at harvesting time. N was also determined at the time of planting and harvesting. Soybeans showed the highest number of nodules while Bambara groundnuts showed the least number of nodules. There was negligible change in P at the zero time and at harvesting time. This is attributed to the applied P which is more available in the top soil. There were higher contents of sulphur at zero time than at harvesting time. On the other hand, there was less nitrogen at zero time than at harvest. There was no significant change in organic carbon contents at zero time and at harvest time.

Citation: Mwanja J. N, (2001). The effect of phosphorus on the growth of Bambara groundnuts (*Vigna subterranea*), groundnuts (*Arachis hypogaeae*) and soybean (*Glycine max*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.25 Effects of phosphorus levels on flowering, pod setting and seed yield of cats whiskers (*Cleome gynandra*)

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A greenhouse experiment was conducted on the effect of phosphorus levels on flowering, pod setting and seed yield in Cat's whiskers (*Cleome gynandra*) and Bunda College of Agriculture in the growing season of 1999/00. Treatments were arranged factorially (2×5) in Completely Randomized Design (CRD). The first factor was two varieties (purple stemmed variety=VP; and white stemmed variety=VW) while the second factor was five levels of phosphorus fertilizer from Diammonium Phosphate (DAP), (where 0 kg/ha=P1, 40 kg/ha=P2, 80 kg/ha=P3, 120 kg/ha=P4 and 140 kg/ha=P5 of P₂O₅) increasing phosphorus level application from 40 kg/ha to 140 kg/ha did not significantly improve flowering, pod setting, seed yield and seed quality. However, the highest number of flowers formed at 0 kg P₂O₅/ha (118 flowers) in white variety and at 140 kg /ha P₂O₅/ha (109 flowers) in purple variety. Flower abortion was highest in both varieties where phosphorus was applied; thus 80.3 % of white variety and 82% for purple variety. Purple formed highest number of pods at 140 kg P₂O₅/ha (22pods) while white variety formed highest number of pods at both 120 kg P₂O₅/ha and 140 kg P₂O₅/ha (15 pods). Seed yield per plant was highest at 140 kg P₂O₅/ha for both varieties (2.9 g/plant for purple variety and 2.8 g/plant for white variety) seed quality was best at 0 kg P₂O₅/ha for both varieties (0.14g/100 seeds).

Citation: Ng'oma S. W.D, (2001). Effects of phosphorus levels on flowering, pod setting and seed yield of cats whiskers (*Cleome gynandra*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.26 Screening grain legumes for nitrogen fertility improvement

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During the 1998/99 rainy season at Bunda College of Agriculture Farm, four grain legumes namely; Bambara groundnuts, soybeans, pigeonpeas and groundnuts were grown in a Split Plot Design, replicated four times to determine the legume type and their varieties that contribute more to nitrogen fertility levels in the soil. Included in the experimental objectives was the need to know how much nitrogen the grain legumes fix, the total nitrogen uptake by the plants and the grain nitrogen content of the plants so as to know how much of the fixed nitrogen is retained by the crops and how much nitrogen they leave in the soil for use by a subsequent non leguminous crop. The results showed that there were no significant differences in %N before planting as well as after planting at $P < 0.05$. But the results showed that there were statistically significant differences in %N in the crops (total nitrogen uptake) and the grain (grain nitrogen content) and in the grain (grain nitrogen content) at $P < 0.05$. This means that grain legumes contribute differently to soil nitrogen fertility levels and hence can promote the productivity of subsequent non leguminous crops such maize differently upon being incorporated back into the soil.

Citation: Kawenda L. A. Z, (2000). Screening grain legumes for nitrogen fertility improvement, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.27 Assessment of the effect of organic and inorganic fertilizers on growth, yield and leaf quality of Burley tobacco (BRK 4 variety)

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Farmers have access to both organic and inorganic fertilizers that are not effectively used to achieve maximum benefits. The study was, therefore, conducted to investigate the combined effects of organic and inorganic fertilizers on growth, yield and leafy quality of Burley tobacco. The five treatments were laid out in a randomized completely block design (RCBD) and replicated four times. BRK 4, a variety of Burley tobacco was planted in the experimental study. Poultry (PM) and cattle manures (CM) were used as organic sources of fertilizers while inorganic sources used were compound D and Calcium Ammonium Nitrate (CAN). The treatments were as follows: (1) T1= 600 compound D kg/ha (basal dressing) +400 CAN kg/ha (top dressing) which was used as a control, (2) T2= 8t PM/ha +400kgCAN/ha, (3) T3= 8t CM/ha +400kgCAN, (4) T4=4t PM/ha +400kg Compound D /ha +400kg CAN and T5=4t CM/ha+400kg Compound D /ha +400kgCAN. Results showed that inorganic fertilizers only (T1) produced the highest results: plant height (84.65 cm); leaf length (58 cm); and nicotine content (2.54%) as compared to the other treatments. Overall, T4 and T5 recorded the second highest values whereas T2 and T3 performed poorly. However, high levels of organic fertilizers in the organic and inorganic treatments (T2 and T3) increased the levels of reducing sugars in the tobacco leaf hence reduced tobacco leaf quality.

Citation: Mbughi A (2015). Assessment of the effect of organic and inorganic fertilizers on growth, yield and leaf quality of Burley tobacco (BRK 4 variety), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.28 Investigation if it is necessary to apply nitrogen fertilizers twice on fine textured soil for good maize yields

N Lamba; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi

The research was carried out at Bunda College of Agriculture, Department of Crop and Soil Sciences Students training Farm during the 2013/2014 growing season. The research was carried out to investigate if it is necessary to apply nitrogen fertilizers twice on fine-textured soil for good maize yield. The experiment was laid in a randomized completely block design with three replicates. Five treatments were used; (T1): split application (normal practice of fertilizer application (23:21:0 +4S + urea); (T2): Nitrogen fertilizer applied once at planting (urea); (T3): nitrogen fertilizer applied once at three weeks after emergence (urea); (T4): 23:21:0 +4S and urea (mixed) applied once at planting; (T5): mixed 23:21:0+4S and urea applied once 3 weeks after emergence. The experiments were laid out in a randomized complete block design (RCBD) with three replicates. The data was then subject to Gen Stat computer package 16th Edition. Data was collected on growth and yield performance. The data was subjected to analysis of variance and means were separated using Turkey test. Rainfall data for the growing season was noted. The results showed that there were no significant differences in the germination percentage, chlorophyll levels at tasseling, plant height (at tasseling and at harvest), stand count at harvest, cob length, number of rows and number of kernels per cob. However, there were significant differences between treatments in chlorophyll at three weeks, plant height at 3 weeks, plant biomass and yield. Since the yields of treatments 4 and 1 were not significantly different, from the research conducted, it can be concluded that split application of fertilizer is not

really necessary on fine-textured soils. This is so because maize grain yields for treatments 2 and 4, where N was applied on once was significantly different from the yield of the split application (recommended). This shows that the leaching of N in the fine textured soil is too high. Finally it can also be concluded that there is reduction in labour demand when N is applied only once

Citation: Lamba A. N, (2015). Investigation if it is necessary to apply nitrogen fertilizers twice on fine textured soil for good maize yields, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.29 The effects of integrate use of farm yard manure (FYM) and inorganic fertilizers on growth, tuber yield and quality of potato.

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A field experiment was conducted to assess the effect of integrated use of farm yard manure (FYM) and inorganic fertilizers on growth, tuber yield and quality of potato. (*Solanum tuberosum*). The study was conducted at Bunda College of Agriculture, Crop and Soil Science Student Research Farm during the 2013/2014 growing season. The treatments consisted of combination of FYM and inorganic PK fertilizers. Swine, cattle, goat and poultry manure were used as sources of organic fertilizers and were applied at 7 t/ha of each type of FYM. Nutrient deficient in the FYM were supplemented with PK fertilizers to balance the nutrients to achieve crop nutrient requirement of 100kg N/ha +100kg P₂O₅/ha +100 kgP₂O/ha as recommended by FAO, 2009. The study had two controls; absolute control of recommended fertilizers rate for potato in Malawi. in total the study consisted of six treatments which were laid out in a randomized completely block design with four replicates. The results demonstrated that application of FYM and inorganic fertilizer significantly increased plant growth, tuber yield and quality of potato over application of full dose of inorganic NPK fertilizer. The maximum number of tubers per plant (13), plant height (59.29 cm), dry weight of shoots (178.2g), nitrogen content (1.877%), protein content (11.169%) and carbohydrate content (40.35%) were recorded in T4 (7t/ha CM+ 74kg P₂O₅/ha +100 kgP₂O/ha). Maximum stand count (14plants), tuber dry weight (204g), total tuber yield (15.92t/ha) and marketable tuber yield (13.532 t/ha) were recorded in T6 (7 t/ha SM +85 P₂O₅/ha +100 kgP₂O/ha) application. Only maximum germination percentage (92.5%) was recorded in control treatment (T1). Therefore, cattle manure enhanced potato tuber quality parameters whereas swine manure enhanced tuber yield. Inorganic plant nutrient management variants were inferior to integration of inorganic and FYM plant nutrient management variants.

Citation: Sinoya H, (2015). The effects of integrate use of farm yard manure (FYM) and inorganic fertilizers on growth, tuber yield and quality of potato, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.30 Effects of planting in pits for water management and maize production

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A field experiment was conducted at Bunda College, Crop and Soil Sciences Teaching and Research Farm during the 2013/14 growing season. Its main aim was to determine the extent to which tillage systems mitigate the adverse effects of in-season temporal shortage of rain on crop growth. The four treatments used were: (1) box ridges, (2) ridges, (3) planting pits and (4) flat land as a control. The test crop was maize, DK 8053 variety. The differences in plant height and moisture contents at planting and at harvesting due to treatments were significantly different ($P < 0.05$) at harvest, the plants grown in the plots had highest moisture content while those grown on the flat had the lowest moisture content. This suggested that the rain water that accumulated in the pits was conducive to a conservation of high contents of moisture in the pits following the localized water lodging conditions that had been created in the pits after the rainfall. The maize grown on the ridges produced the highest cob weights followed by the weights of the cobs produced by plants grown on the flat land (control) and then by the weights of cobs produced by plants grown on box ridges. The maize lodging conditions that had been created in the pits had adverse effect on the crop yield. The cropping season received normal rains which may explain why the differences in moisture yield and yield components due to treatment effects were not statistically significant.

Citation: Phiri M (2015). Effects of planting in pits for water management and maize production, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.31 Assessing the residual nutrients of *Tithonia diversifolia* and *Senna spectabilis* biomass on maize production

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Effects of residual nutrients of *Tithonia diversifolia* and *Senna spectabilis* biomasses on growth, yield and yield components of maize was assessed at Bunda College Department of Crop and Soil Science Student Research Farm on plots where biomasses were applied and maize was grown during the past two growing seasons (2011/12 and 2012/13). The study was a randomized completely block design with eight treatments which were replicated four times. The treatments which were used for the past two growing seasons included: (i) control, no input; (ii) recommended rate of fertilizer application of 92 kg N/ha; (iii) 46kg N/ha from *Tithonia* and 46kg N/ha CAN as top dress; (iv) 92 kg N/ha as basal dress and 46kg N/ha from CAN as top dress; (v) 92 kg N/ha from *Tithonia* once; (vi) 92 kg N/ha from *Senna* applied once; (vii) 46 kg N/ha from *Tithonia* as basal and 46 kg N/ha from *Tithonia* as top dress; (viii) 46 kg N/ha from *Senna* as basal and 46 kg N/ha from *Senna* as top dress. No fertilizers were applied in the third year to assess the effects of residual nutrients from the biomasses used for the past two growing seasons. Results showed that maize yield and yield components from the plots of *Senna spectabilis* biomasses were significantly higher compared to the yield and yield components from the control ($P < 0.05$). *Senna spectabilis* (T6) has been used for the past two growing seasons and has the tendency of rate mineralization rate due to increased levels of lignin, fiber and polyphenols which retards the activities of microorganisms in the decomposition and mineralization processes. The results also showed significant differences in maize growth parameters between the plots where *Senna* biomasses have been incorporated for the past two growing seasons prior to 2013/14 and the control ($P < 0.05$) where T6 (*Senna* applied once) recorded higher plant and cob heights while T8 (*Senna* applied as both basal dress and top dress) produced higher cob length. While in the plots where *Tithonia diversifolia* have been incorporated for the past two seasons showed slightly lower plant growth, yield and yield components due to fast mineralization tendency due to lower polyphenols, lignin and fiber content which do not affect the activities of microorganisms to mineralize and decompose the biomass hence they mineralize and decompose easily. In conclusion, residual nutrients from *Senna spectabilis* can increase or maintain maize growth, yield and yield components.

Citation: Malunga J (2015). Assessing the residual nutrients of *Tithonia diversifolia* and *Senna spectabilis* biomass on maize production, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.32 The effects of varying nitrogen and potassium rates on yield and yield components of potato (*Solanum tuberosum*)

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The aim of the study was to assess the effects of varying nitrogen and potassium fertilizer rates while maintaining phosphorus constant on the yield and yield components of potato (*Solanum tuberosum* L). The study was carried out at Bunda College Campus, Department of Crop and Soil Science Research Farm during 2013/14 growing and was laid in randomized completely block design with five treatments (0kg N/ha, 50kg N/ha, 100kg N/ha, 150kg N/ha, 200kg N/ha) and (0kg P/ha, 50kg P/ha, 100kg P/ha, 150kg P/ha, 200kg P/ha) that were replicated three times. The required nutrients were sourced from triple superphosphate (TSP), muriate of potash (MOP) and 23:21:05. Fertilizers were banded and applied and sprouted Violet tubers dropped at 30 cm apart and buried. Data collected on the number of tubers/plant, tuber diameter, nitrogen and carbohydrates content and total tuber and marketable tuber yield per hectare as well as the tuber weights were analyzed using Gen Stat statistical package, one way ANOVA and the means were separated. The results obtained showed increase in nitrogen and potassium increased tuber yield but decreased tuber diameter and marketable tuber size. Highest number of marketable tuber size were produced at 150 kg N/ha +100 kg P₂O₅ +150 kg K₂O/ha whilst nitrogen rate of 200 kg N/ha +100 kg P₂O₅ +200 kg K₂O/ha produced higher number of small tubers. Nitrogen, protein and carbohydrate contents in tubers increased with increase in both nitrogen and potassium but at a highest rate started decreasing. High nitrogen rate increased dry top weights but decreased the tuber dry weights. Despite the case, nitrogen rates 50kg N/ha, 100kg N/ha and 150kg N/ha produced the highest dry tuber weights. Therefore, nutrient rates of 150 kg N/ha +100 kg P₂O₅ +150 kg K₂O/ha should be used for potato production at Bunda College.

Citation: Sukani J (2015). The effects of varying nitrogen and potassium rates on yield and yield components of potato (*Solanum tuberosum*), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.33 Effects of time of planting pigeonpeas on productivity of intercropped maize (*Zea mays*) and pigeonpeas (*Cajanus cajan*)

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Research to find out the effect of time of planting pigeonpeas in maize-pigeonpea intercrop was conducted at Bunda College Crop and Soil Science Students Research Farm during the 2013/14 growing season. There were five treatments: sole maize, sole pigeon pea, maize-pigeon intercrop, pigeonpea planted at the same time with maize, maize-pigeonpea intercrop, pigeon pea planted once week or two weeks after maize. The experiment was laid out in randomized complete block design with three replicates. Time of planting pigeonpeas in the intercrop had no significant effect on growth, yield and yield components ($P < 0.05$). However, time of planting pigeonpeas had significant effects of height, days to 50% flowering, grain weight, 100 seeds weight and total biomass of pigeonpea ($P < 0.001$). Lowest number of days to 50% flowering of pigeonpea were recorded when pigeonpea time of planting was delayed by one week (136 days) followed by intercrops when maize-pigeonpea intercrop were planted simultaneously (143 days) or 2 weeks (147 days). LER ranged from 1.05 (with delayed time of planting) to 1.16 (when the two crops were planted simultaneously). It is recommended that in maize-pigeonpea intercrop, pigeonpea can be planted either simultaneously or one week after maize.

Citation: Matupi J, (2015). Effects of time of planting pigeonpeas on productivity of intercropped maize (*Zea mays*) and pigeonpeas (*Cajanus cajan*), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.34 Effect of calcium on groundnut yield and quality

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A field experiment was conducted at Bunda College, Crop and Soil Sciences Student Research Farm during the 2013/2014 growing season and the trial was done in order to assess the effect of calcium on groundnut yield and quality. Three levels of calcium (1280kg/ha, 1700 kg/ha and 2133kg/ha) was applied before planting and at pegging stage. The treatments were laid out in a randomized complete block design (RCBD). Soils were analyzed for organic carbon, pH, textural class, potassium, magnesium and calcium. Data was collected on phenology, vegetative development and yield and yield components. The results from the study revealed that the application of 2133 kg/ha of lime (80gCa) before planting significantly increased growth parameter such as plant height and canopy spread. The above amount of calcium applied before planting increased the yield as well as biomass. Treatment 6 produced the highest plant height, canopy spread, yield and biomass. From the results of the trial, it can be concluded that application of 2133kg/ha (80gCa) before planting will boost groundnut yield.

Citation: Tsambalikagwa L (2015). Effect of calcium on groundnut yield and quality, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.35 Effects of conservation agriculture on nutrient dynamics and soil respiration

E Binali; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi

An experiment was set up at Bunda College soils laboratory after collecting soil samples from Conservation Agriculture (CA) field trials that have been set and run for three years. The experiment was designed out to find out the effects of CA practices on soil respiration and nutrient dynamics. Treatments consisted of two practices (zero tillage: conservation agriculture (CA1), and mulching: conservation agriculture (CA2) and control (ridging: conventional agriculture). The three treatments were arranged in randomized completely block design (RCBD) in the field and each treatment replicate four times, however, after collecting samples at 25 cm deep, samples were set in Randomized Complete Design in the laboratory. Soil samples were collected using open auger and a diagonal line was drawn on each lot and samples were collected along the line. Three random samples were collected per plot making a total of 36 samples. These soil samples were air dried and crushed before running the soil analysis. Soil samples were analyzed for: soil organic matter, pH, phosphorus, and total nitrogen. Soil respiration rates were also obtained after incubating the samples. The data was analyzed using GENSTAT 15th edition and ANOVA was used to test the quality of the means. The results showed that CA practices increases soil microbial activities as indicated by the significant differences ($p < 0.05$) on soil respiration. Conservation agriculture increased soil pH ($p < 0.001$) and phosphorus ($p < 0.05$). However, at three years CA showed no significant differences in total nitrogen and SOM in the treatments.

Citation: Binali E (2015). Effects of conservation agriculture on nutrient dynamics and soil respiration, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.36 Assessment of pigeonpea residual fertility on maize yield and yield components**R Phiri; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi**

A study was conducted at Bunda College, Department of Crop and Soil Sciences Student Research Farm during the 2013/14 growing season. The experiment was laid out as a randomized completely block design on a site on which pigeonpea was previously planted. The main objective was to assess the effect of rate of nitrogen and phosphorus fertilizer that farmers would apply to complement the pigeonpea residual fertility. A maize hybrid variety, SC 627 (Mkango) was planted. Results showed that 92 kg N/ha + 40 kg P₂O₅/ha gave significant high plant height, cob placement height, number of cobs, number of kernels, seed size and grain yield. Both N and P were important in increasing yield and yield components. It is recommended that 92 kg N/ha +40 kg P₂O₅/ha is the best fertilizer recommendation.

Citation: Phiri R, (2015). Assessment of pigeonpea residual fertility on maize yield and yield components, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.37 Effect of incorporating organic materials into the ridge on growth and yield beans (*Phaseolus vulgaris*)**K Malola; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi**

The paper was written to confirm whether the observation of some smallholder farmers was true that organic materials have adverse effects on beans. To confirm this several organic materials: *Tithonia diversifolia*, *Urochloa mosambicensis*, *Panicum maximum*, *Hyperrhnia fufa*, *Eleusine indica*, *Commelina banghalensis*, *Cynodon dactylon*, *Cyperus rotandus*, *Richardia scabra* and *Bracharia decumbens* were incorporated in ridges which were planted with beans of the variety Kalima. The experiment was laid in a Randomized Completely Block Design and replicated three times with six treatments. Five treatments were incorporated with organic materials and one was not incorporated with any organic materials. The data was analyzed using Gen-Stat computer package. The results showed that there was death of more plants in treatments that were incorporated with organic materials. Significant differences ($p < 0.05$) were obtained on the number of death plants. The treatment which mixed organic materials consistently had the highest number of dead plants from the week the beans started dying to the week of harvest. The highest yield was obtained from the treatment that was incorporated with mixed organic materials (458.1 kg/ha). The death of beans was caused by a root maggot called *Dellia platura*. The maggot was attracted by incorporated organic materials.

Citation: Malola K. Effect of incorporating organic materials into the ridge on growth and yield beans (*Phaseolus vulgaris*), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.38 A comparative study of the soil management effects on soil quality indicators**P Mlauli; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi**

The soils used in this investigation were acidic in their reaction and those that were subjected to conventional tillage (CvT) became more acidic. This suggested that increased humification and mineralization of soil organic materials might have contributed towards increased acidity. The increased biodegradation of organic matter in the soil that had been under CvT resulted in the soil having lower organic matter content than those that had been under either no tillage (NT) or conservation tillage (CsT). The beneficial effects of increased contents of organic matter in those soils that had been under NT or CsT are reflected by improved chemical properties of the soil. It is therefore recommended that farmers should be encouraged to maintain adequate content of organic matter by using either using any of the tillage systems that are conducive to increased soil organic matter contents in the soil or returning crop residue to the soil. The results have also shown that the use of different tillage systems may promote increased heterogeneity of the soils.

Citation: Mlauli P (2015). A comparative study of the soil management effects on soil quality indicators, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.39 Maize yield performance in cassava-maize rotation

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An experiment was carried out at Bunda College of Agriculture, Department of Crop and Soil Science Students Research Farm during the 2013/14 growing season to investigate the effect of different NK combination rates on growth and yield of maize grown on a plot where cassava was previously grown. The treatment combinations were; (i) nil; 92 kg N/ha; (ii) 35 kg N/ha +50 kg K₂O/ha; (iii) 35 kg N/ha +100 kg K₂O/ha; (iv) 92 kg N/ha +50 kg K₂O/ha and; (v) 92 kg N/ha +100 kg K₂O/ha which were compared in a randomized complete block design and replicated three times. Seedling establishment, plant height, cob height and grain yield were significantly affected by different rates of NK fertilizer combinations. On the other hand, cob length, number of cobs per treatment, stand count at harvest and seed size, were not significantly affected by different NK fertilizer combination rates ($p < 0.05$). T5 (92 kg N/ha +100 kg K₂O/ha) outperformed other treatments and the lowest was from the control which was due to low nutrient levels which were left after cassava was removed. However, too low or high NK combination levels reduced maize seed size. The explanation is that nutrients were too low for effective grain filling or too high and remained in maize biomass.

Citation: Phambala K, (2015). Maize yield performance in cassava-maize rotation, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.40 Effects of phosphorus and boron application on biological nitrogen fixation (BNF) and yield of pigeonpea (Cajanus cajan)

E Malunda; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi

This study was done to investigate the effect of phosphorus and boron application on biological nitrogen fixation (BNF) and yield of pigeonpea (*Cajanus cajan*). The experiment was conducted at LUANAR, Crop and Soil Sciences Department Students Research farm during the 2013/14 growing season. The treatments included pigeonpea that was not applied with any fertilizer, pigeonpea that was applied with P and B only and a combination of both P and B. The experiment design was randomized completely block design (RCBD) with three replicated and five treatments. The amount of nitrogen fixed per hectare was estimated using modified nitrogen difference method. Results showed significant difference ($p < 0.05$) in the total amount of biological nitrogen fixed nitrogen. The P +B treatment combination showed significantly ($p < 0.05$) higher amount of biologically fixed nitrogen by 54% than the control treatment. The lowest values of all the parameters were found in the control treatment. Among the growth parameters; plant height and dry weight /plant were highest in P+B treatment combination. Days to flowering to flowering were low in P+ B treatment combination but high in the control treatment. Among the yield attributing characters i.e. number of total pods/plant, 100 seed weight/plot and seed yield per hectare were highest in the P+B treatment combination. It can be concluded that the application of both phosphorus and boron were the most effective treatment for increasing the amount of biologically field nitrogen and yield of pigeonpea.

Citation: Malunda E (2015). Effects of phosphorus and boron application on biological nitrogen fixation (BNF) and yield of pigeonpea (*Cajanus cajan*), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.41 Evaluation of Bambara groundnuts (Fabaceae) yield response to supplementary fertilizer applied at different rates as basal dressing

M Chakwamba; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi

Research was conducted at Bunda College of Agriculture Students' Farm during the 2011/12 growing season. The research conducted in order to find out the importance or advantage of strategic application of nitrogen fertilizers to Bambara groundnut (*Fabaceae*) as basal dressing. The experiment had four treatments, where T1 was a control with zero fertilizer rate, T2 (25 kg of 23:21:0 +4S), T3 (50 kg of 23:21:0 +4S) and T4 (100 kg of 23:21:0 +4S). The most commonly used Bambara groundnut variety, Kayera was used. The experiment was randomized complete block design in a one way analysis of variance (ANOVA). The fertilizer application rates from 25 kg to 100 kg per hectare had no effect on yield and yield components of Bambara groundnuts at $p = 0.05$, although there was an observation increasing trend in yield.

Citation: Chakwamba M (2013). Evaluation of Bambara groundnuts (*Fabaceae*) yield response to supplementary fertilizer applied at different rates as basal dressing, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.42 Insect fauna in conservation agriculture system at Bunda, Lilongwe

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Conservation agriculture has been proposed as widely adapted set of management principles that can assure more sustainable agricultural production. It therefore increases insect diversity while conventional tillage lessens biodiversity (which include insects) overtime. This study was initiated to document insect fauna associated with CA. The study was conducted at Bunda College of Agriculture, Department of Crop and Soil Sciences Students' Research Farm during the 2013/14 growing season. Two fields of CA and Ct were set and each replicated three times. Insects were collected in all the fields in the morning before 9 O'clock using pitfall traps, hand picking and aerial nets. The species diversity in the CA was 1.299 while in CT it was 0.176. This means diversity in CA was higher than of CT. CA was rich with species of insects compared to CT. This study conducted in the initial year of CA therefore another study has to be conducted to find out other insects associated with CA.

Citation: Manong'a T, (2014). Insect fauna in conservation agriculture system at Bunda, Lilongwe, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.43 Evaluation of the effects of organic matter- urea combination on maize yield

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A study was conducted to evaluate the effect of organic matter-urea combination on maize yield. The main objective of this study was to improve the effective use of urea fertilizer so that there is less leaching and to develop a way on how the little available fertilizer can be used effectively by reducing costs incurred in purchasing these fertilizers. A lot of urea is easily lost in the soil through leaching since urea is not readily available to plants because it has to undergo transformation first. Introduction and promotion of organic matter and urea combination required prior research to know if it can perform better and give higher yield under Malawian climatic and small-scale farmer conditions. Cattle manure and urea were used in this experiment. The experiment had six treatments: T1 (maize with no manure, urea only, recommended rate (150 kg/ha)); T2 (maize with manure only, no urea, recommended rate (10 ton/ha)); T3 (maize with urea only, no manure, half recommended rate, 75 kg/ha); T4 (maize with manure only no urea, recommended rate, 5 ton/ha); T5 (maize with both urea and manure, recommended rate, 150 kg/ha + 10 ton/ha) and T6 (maize with both urea and manure half recommended rate (75 kg/ha + 5 ton/ha)). These were laid in randomized complete block design replicated three times. The maize variety used in this experiment was DKC 8053 (Mkangala). Data were collected on: germination percentages, rainfall distribution, plant height, number of rows/plant, harvest index, cob length, stand count at harvest, biomass as well as grain yield. Normal agronomic husbandry practices were undertaken such as weeding and harvesting was done at 3.5 months after planting (MAP). The soils at the site of the experiment were analyzed in the laboratory prior to urea application and after urea application. The results showed that grain yield had significant difference. Other components which showed significant differences were plant height, number of rows/plant, harvest index, cob length and biomass. However, there was no significant difference on stand count at harvest among the treatments. T5 and T6 gave highest grain yields. However, T3 gave the lowest grain yield. Based on the results it was concluded that: A combination of full rate (10 ton/ha) cattle manure and full rate (150 kg/ha) urea fertilizer significantly increased the grain yield of maize; The application of half rate of half rate (5 ton/ha) cattle manure and half rate (75 kg/ha) urea fertilizer had similar effect on yield to that of (10 ton/ha) cattle manure and full rate (150 kg/ha) inorganic fertilizer. It can also be concluded that organic manure and urea fertilizer combination increases the soil pH as well as soil nutrient levels. This has been evidenced by the increase of those parameters in treatments which comprised of organic matter and urea fertilizer.

Citation: Malata HN (2014). Evaluation of the effects of organic matter- urea combination on maize yield, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.44 Investigation of effect of intercropping pigeonpea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*) on biological nitrogen fixation and crop yield

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Biological nitrogen fixation (BNF) is one of the strategies to improve soil nitrogen and crop productivity in N limited environments. A study was conducted during the 2011/12 growing season at Bunda College of Agriculture to investigate the effect of intercropping pigeonpea with cowpeas on BNF and yield. Four treatments; pure pigeonpeas, pure cowpea, pigeonpea-cowpea intercrop and maize were grown in a randomized complete block design replicated three times. The N difference method was used to estimate BNF.

The results showed that there were significant differences among the cropping systems with regard to N fixation. Cowpea +pigeonpea intercrop fixed the highest amount of 71 kg N/ha followed by pure stand of pigeonpea 51 kg N/ha and the lowest was cowpea 40 kg N/ha. The results also showed that there was no significant difference on the grain yield and leafy biomass between the pure stand of pigeonpea and pigeonpea intercropped with cowpea. Pure stand pigeonpea yielded 768kg/ha of grain and 2566 kg/ha of leafy biomass. The results further showed that there was no significant difference on grain and leafy biomass yield between pure stand cowpea and cowpea intercropped with pigeonpea. Pure stand cowpea yielded 900 kg/ha of grain and 1869 kg of leafy biomass while cowpea intercropped with pigeonpea yielded 781 kg/ha of grain and 1642 kg/ha of leafy biomass.

Citation: Tembo M, (2013). Investigation of effect of intercropping pigeonpea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*) on biological nitrogen fixation and crop yield, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.45 Assessment of effects of inorganic NPK fertilizer sources on yield and quality of cotton (*Gossypium hirsutum* L) at Bunda College

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A field study on the effect of inorganic NPK fertilizer on seed cotton yield and quality of cotton (*Gossypium hirsutum* L) was carried out during the 2011/12 growing season at Bunda College of Agriculture, Department of Crop and Soil Sciences Students' Research Farm. Three NPK fertilizers from companies: Yara Super D (8:24:20+6S +0.15B); Nyiombo NPK (23:21:0+4S) and Malawi fertilizer NPK (23:21:0+4S) were applied as basal fertilizer to cotton, IRM81 variety and a control (without fertilizer). The experiment had four treatments laid out in a randomized complete block design replicated four times. Data collected included plant height measured fortnightly (four weeks after emergence) to harvesting; number of branches per plant, bolls per plant; moles and seed cotton yield. Seed cotton samples were sent to Makoka Agricultural Research Station for analyses of ginning out turns, lint and seed weights, and fiber length. Fertilizer samples were analyzed for nitrogen, phosphorus and potassium content of each of the three fertilizer companies. Analyses showed that NPK nutrients from all the fertilizer companies were lower than the fertilizer grades on the bags. Nyiombo, Malawi Fertilizer Yara showed and average of 22, 20.3 and 6.2 % for nitrogen percentages, respectively, against 23, 23, and 8% grades displayed on the bags, respectively, while Nyiombo NPK fertilizer revealed the an average of 18%, Malawi and Yara NPK fertilizers revealed 17.6 and 19.8 % for phosphorus percentages, respectively, against 21, 21 and 24 % grades displayed on the bags, respectively. Yara NPK fertilizer showed 17.1 percentage of potassium against 20% grade displayed on the bags. However, all NPK fertilizer companies nutrients analyses were below the allowable variation stipulated in the Fertilizers, Farm Feed and Remedies Act No. 4 of 1996, except for nitrogen in the Nyiombo fertilizer. Data was subjected to analysis of variance (ANOVA) using Gen-stat Statistical package 14th edition and Duncan Range Test (DMRT) was used to separate the means at 5% significance level. Some components showed significance difference as a result of applying different fertilizer sources: these included plant height ($p \leq 0.048$); lint weight ($p \leq 0.036$); and seed cotton yield ($p \leq 0.037$). Nyiombo NPK fertilizer gave the tallest plants (87 cm); more number of branches (21) and bolls (15); and highest lint weight 205 kg/ha and seed cotton yield (657 kg/ha). Overall, statistical differences were shown in number of moles per plant ($p \leq 0.056$); fiber length ($p \leq 0.934$); ginning out turns (GOT) ($p \leq 0.481$); and seed weight ($p \leq 0.321$). Overall Nyiombo fertilizer outperformed the other two fertilizer sources in the parameters recorded. These results, therefore, suggested that Nyiombo NPK fertilizer is the a good fertilizer to improve quality and seed cotton yield especially in the mid plateau areas represented by the Bunda College site where this experiment was carried out

Citation: Kalumba JP (2013). Assessment of effects of inorganic NPK fertilizer sources on yield and quality of cotton (*Gossypium hirsutum* L) at Bunda College, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.46 Maize yield response to *Sesbania sesban* and *Tithonia diversifolia* following one and two year fallows

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A study was conducted during the 1999/2000 cropping season at Bunda College of Agriculture Staff and Student Research Farm, 30 km from Lilongwe city, the capital of Malawi, to investigate the maize yield response to one or two year improved fallow periods involving *Sesbania sesban* and *Tithonia diversifolia*. The experiment utilized the four nitrogen sources (0 kg N, 40 kg N, *Sesbania sesban* and *Tithonia diversifolia*, and two fallow periods (one year or two year). These experiments were laid out in plots as a 4 x 2 factorial experiment in Completely Randomized Block Design (CRBD) with three replicates per treatment combination. Each plot measured 10m x 10m, with 90 cm between plots and 200 cm between replicates to factor out shading effect on the net plots. A maize hybrid variety (MH18) was used as a test crop. Data collected included maize grain yield, stover weights and plant height calculated on hectare basis.

Data was analyzed using MSTATC computer package and Duncans Multiple Range Test was used to separate the means where they showed significant differences ($P < 0.05$). There were significant differences ($P < 0.05$) in grain yield between *Sesbania sesban* and *Tithonia diversifolia* fallows. *Sesbania sesban* gave high yields of maize (3029.86 kg/ha) than *Tithonia diversifolia* 2053.33 kg/ha). There were no significant differences in stover weight ($P < 0.05$) between the two MPTs but there were significant variations between the two fallow periods (higher in 2 year fallow period). Plant height were also varied significantly ($P < 0.05$) between the MPTs (higher in *Sesbania*) but there were no significant difference between the fallows periods. In general, *Sesbania sesban* performed better in all aspects. From these results, it is concluded that a smallholder farmer would benefit more from the two year fallow than from a one year fallow. In terms of the MPTs, the results indicate that *Sesbania sesban* would give high yields of maize than *Tithonia diversifolia* fallows.

Citation: Luwanga C, (2001). Maize yield response to *Sesbania sesban* and *Tithonia diversifolia* following one and two year fallows, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.47 The effect of phosphorus on the growth of pigeonpeas (*Cajanus cajan*), velvet beans (*Mucuna pruriens*), and poison fish beans (*Tephrosia vogelii*)

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An experiment was carried out at Bunda Students Research Farm which is at altitude of 33°- 45' S and 14° 11'E. The area is at altitude of 1020 metres above the sea levels. Soils belong to the Lilongwe series, which is ferruginous latosol. The soils are sandy clay loam with a moderate fine crumb and are slightly sticky, plastic, friable and slightly hard. An experiment was a split plot laid down in randomized complete block design. The main plots were the crop species i.e. *Zea mays*, *Cajanus cajan*, *Tephrosia vogelii* and *Mucuna pruriens* with *Zea mays* as a control. Treatments i.e. 0, 20 and 40 kg P/ha were the subplots. The source of P was 23:2:4+4S. The crops studied responded differently to applied P treatment levels. This was expressed through significant increases in number of seeds per pods, number of pods per branch, number of branches per plants, and through a general increase in biomass accumulation; N, P and S content in shoot and roots; and N and P in seeds. In a nutshell, *Tephrosia vogelii* produced the highest biomass at an economic P application rate as compared to the other legumes which needed much more P to attain maximum growth. A medium to high percent of organic carbon (up to 2.84%) in this soil resulted into a high C: N ratio. Since different crop species utilize different pools of soil P, available P at harvest was significant affected by the three crops species.

Citation: Nyirenda M A (2001). The effect of phosphorus on the growth of pigeonpeas (*Cajanus cajan*), velvet beans (*Mucuna pruriens*), and poison fish beans (*Tephrosia vogelii*), Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.48 Performance of groundnut-pigeonpea intercrops as affected by the time of planting

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Time of planting in intercropping systems is one of the factors that can affect crop productivity. A study was conducted at Bunda College, Crop and Soil Science Student' Research Farm during the 2011/12 growing season to investigate the effect of time of planting on the performance of groundnut-pigeon intercrops. The study involved five treatments namely; sole groundnuts, soil pigeonpea, groundnut-pigeonpeas intercropped with pigeonpea planted simultaneously, groundnut-pigeonpea intercropped with pigeonpea planted one week later and groundnut-pigeonpea intercropped with pigeonpea planted two weeks later. The treatments were allocated to different plots in a randomized complete block design (RCBD). Grain yield and leafy biomass were assessed in the study. The results indicated that sole treatment the highest grain yields for both groundnuts and pigeonpeas (984 kg/ha and 411 kg/ha respectively) than grain yield of intercropped treatments. From treatment; groundnut-pigeonpea intercropped with pigeonpea planted simultaneously, grain yield for groundnut was 449kg/ha and for the pigeonpea was 205 kg/ha. From treatment the groundnut-pigeon intercropped with pigeonpea planted one week later, grain yield for groundnut was 607kg/ha and for the pigeonpea was 300 kg/ha. From treatment the groundnut-pigeon intercropped with pigeonpea planted two weeks later, grain yield for groundnut was 775kg/ha and for the pigeonpea was 384 kg/ha. Based on productivity, intercropped groundnut was more productive than sole groundnut. Among intercropped treatments, groundnut-pigeonpea intercrop with pigeonpea planted two weeks later produced higher grain yield and higher Land Equivalent Ratio (1.72) than other intercropped treatments. Therefore, planting pigeonpea two weeks later in the groundnut-pigeonpea intercrop is the best groundnut-pigeonpea intercropping system since it results into high yield of groundnut and pigeonpea. This intercropping system is also advantageous in terms of land utilization since it results into high Land Equivalent Ratio.

Citation: Phiri A (2013). Performance of groundnut-pigeonpea intercrops as affected by the time of planting, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.49 Effects of pigeonpea density on yield of groundnuts and pigeonpea intercrop

N Chanza; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi

In the 2011/12 growing season, a field experiment was conducted at Bunda College of Agriculture Student Research Farm on intercropping groundnuts (*Arachis hypogaea*) and pigeonpea (*Cajanus cajan*), with the objective of assessing the effect of pigeonpea density on performance of groundnuts and pigeonpea intercrop (GNPP) in terms of yield and yield components. Changing the pigeonpea density from 12350, 24690 to 37000 plants per hectare had no effect on plant height of groundnut from four weeks after planting to early reproductive stage (16 weeks after planting) and grain yield. However, the height of pigeonpea was reduced probably due to intraspecific competition. Increasing density of pigeonpea in GNPP increased pigeonpea biomass per unit area. On per plant basis, pigeonpea density in the GNPP had no effect on grain yield of pigeonpea but reduced leafy biomass by 32% at density 24690 and 37000. Intercropping groundnuts and pigeonpea was advantageous than sole of either of the crop with LER 1.42 when groundnut was intercropped with pigeonpea at pigeonpea density of 37000 plants per hectare

Citation: Chanza N, (2013). Effects of pigeonpea density on yield of groundnuts and pigeonpea intercrop, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.50 Assessing the effects of *Tithonia diversifolia* and *Senna spectabilis* biomasses as source of nutrients for maize production

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This study was set to address soil fertility decline on smallholder farmers' farm in Malawi especially with low utilization of inorganic fertilizers due to limited resources. Likewise, traditional organic inputs alone cannot supply adequate nutrients. The use of two nontraditional organic sources, *Tithonia diversifolia* and *Senna spectabilis* biomasses, and in combination with CAN fertilizer to supply 92 kg N/ha for maize production was investigated at Bunda College of Agriculture, Department of Crop and Soil Sciences Students' Research Farm during the 2011/12 growing season. Treatments included: 1) control, no inputs, 2) recommended fertilizer rate of 92 kg N/ha (from 23:21:0+4S as basal dress and CAN as top dress); 3) 46 kg N/ha from *Tithonia* as basal dress and CAN at 46 kg N/ha as top dressing; 4) 46 kg N/ha from *Senna* as basal dressing and CAN at 46 kg N/ha as top dressing; 5) 92 kg N/ha from *Tithonia* applied once as basal dressing; 6) 92 kg N/ha from *Senna* applied once as basal dressing; 7) 46 kg N/ha from *Tithonia* as basal dress 46 kg N/ha as top dressing; 8) 46 kg N/ha from *Senna* as basal dressing and 46 kg N/ha as top dressing. Maize yield from application of *Tithonia* and *Senna* biomass with or without inorganic fertilizer, were significantly different ($P < 0.05$) from the control. *Tithonia* and *Senna* biomass alone produced maize yields similar to treatments from biomasses were applied in combination with CAN fertilizer. Maize yield from *Tithonia* and *Senna* treatments which were split applied were significantly ($P < 0.05$) lower than where *Tithonia* and *Senna* were applied as single application or top dressed with CAN fertilizer. Results showed that *Tithonia* and *Senna* can equally produce high maize yields as sole sources of nutrients or with the addition of CAN fertilizer.

Citation: Chiponde M, (2013). Assessing the effects of *Tithonia diversifolia* and *Senna spectabilis* biomasses as source of nutrients for maize production, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.51 Response by maize to residual effects of green manure additions from *Tithonia diversifolia*, *Tephrosia vogelii* and *Sesbania sesban*

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The rotation of maize with fast growing nitrogen fixing trees (Improved fallows) can increase soil fertility and crop yields on nitrogen-deficient soils. The overall objective of the experiment was to investigate the response by maize to residual effects of green manure additions from *Tithonia diversifolia*, *Tephrosia vogelii* and *Sesbania sesban*. The specific objectives were to: 1) assess the soil fertility status attributed to the residual effect of green manure addition from *Tithonia*, *Tephrosia* and *Sesbania* and 2) determine the responses by maize to residual effect of green manure additions from one or two year fallows of *Tithonia*, *Tephrosia* and *Sesbania*.

Three fallow species (*Tithonia diversifolia*, *Tephrosia vogelii* and *Sesbania sesban*) of one or two year duration were investigated. The the inorganic sources of fertilizer namely; 0 kg N/ha and 40 kg N/ha served as control treatments; 23:21:0+4S and Calcium Ammonium Nitrate provided sources of basal and top dressing inorganic fertilizers respectively. The results showed significant increases ($p < 0.001$) in the response of yield of maize to residual effect of green manure additions. A two year *Sesbania sesban* fallow gave the highest maize grain yield (2935 kg/ha). However, the overall results indicated highest maize grain yield in the 40 kg N /ha treatment (3499 kg/ha). There were no significant differences ($p < 0.05$) in the soil nutrient content attributed to green manure additions.

Citation: Charlie HJ (2004). Response by maize to residual effects of green manure additions from *Tithonia diversifolia*, *Tephrosia vogelii* and *Sesbania sesban*, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.52 Assessment of the effects of different rates of foliar application of boron on yield ad quality of cotton (*Gossypium hirsutum*)

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Presently, cotton (*Gossypium hirsutum*) ranks fourth as Malawi's foreign exchange earner. The objective of the Malawi government is to increase cotton production and quality in order to meet local demand and export any surplus. Cotton production in Malawi has declined I the pasr 15 years for many different reasons. One of these reasons is decreased soil fertility of the soils. Boron, in particular, is very low and must be introduced into the production system. Traditionally, in Malawi, boron is applied directly to the soil as a nutrient in compound NPK fertilizers. Foliar boron application has more immediate effects than soil applied boron and ensures a rather uniform application. Foliar boron application accelerates the translocation of nitrogen compounds, increases protein synthesis and stimulates fruiting. Boron plays an important role in the development ans retention of squares, fruits and seed development. Cotton is sensitive to boron deficiency because of its high boron requirement especially durin the reproductive stages of growth. Hence, it is important to ake sure that cotton is exposed to adequate amount of boron. Cotton variety IRM 81 was platd at Bunda College, Department of Crop and Soil Science Student Research Farm in the 2011/12 growing season. Four boron rates of 0.0, 0.14, 0.28 and 0.56 kg B/ha were foliar applied onto the leaves of the cotton plants. These four treatments were laid out in a randomized complete block design. Results showed that boron rates significantly ($p < 0.05$) affected seed cotton yields but did not significantly affect plant height, branches per plant, boll number, or mole number. From the study, 0.56 kg B/ha was the appropriate application rate for increased seed cotton weight, seed weigh, and lint weight. This project should be repeated in other ecological zones to find out the effects in those areas.

Citation: Chilima TL (2013). Assessment of the effects of different rates of foliar application of boron on yield ad quality of cotton (*Gossypium hirsutum*), Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.53 Response of sweet potato to cattle manure rates with and without inorganic fertilizer amendment at Bunda College

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A study was carried out during 2012/13 cropping season at Bunda College of Agriculture, Department of Crop and Soil Science Student's Research Farm to evaluate the response of cassava (*Manihot esculenta* Cratz.) to cattle manure with and without inorganic fertilizer. Cattle manure and NPK were used in the experiment. The treatments were laid in randomized complete block design (RCBD) replicated four times. The treatments comprised of 3 levels of cattle manure (0, 5 and 10 t/ha) and 2 levels of inorganic fertilizers (NPK) (0 ad 200kg/ha). The cassava variety that was used in this experiment was Mbundumali, a variety that take 9-15 months to mature and has a potential yield of 25 tons/ha. Data was collected on: plant height number of tubers per plant, tuber mean weight, tuber dry matter (%), tuber fresh yield, harvest index, canopy diameter, tuber length, and tuber diameter. Normal husbandry practices such as weed and pest control were under-taken and harvesting was done at 11 weeks after planting (WAP). The manure and soils at the site of the experiment were analyzed prior to planting. The analyzed soil was high in available P and was low in organic matter (OM), nitrogen (N), and potassium (K). the cattle manure was high in organic matter as compared to that of soil samples whereas N, available P and K were relatively low in the cattle manure. Data collected was subjected to analysis of variance (ANOVA) using Genstat Statistical package (16th edition) and Fisher's Unprotected LSD to separate the means at 5% significance level. The tuber fresh weigh was significantly increased by application of both cattle manure ($p = 0.043$) and inorganic fertilizer ($p = 0.001$) whereas the combination of both cattle manure and inorganic fertilizer was not significantly different ($p = 0.746$) among the treatments.

Optimum tuber fresh yield of 27 620 kg/ha were obtained from application of cattle manure (5t/ha) however increasing the rate of cattle manure to 10 t/ha did not increase the tuber yield further. Manure helps to improve the physical and chemical properties of soil, therefore application of manure (5 t/ha) is recommended in order for farmers to increase production in cassava

Citation: Kabia L.M, (2013). Response of sweet potato to cattle manure rates with and without inorganic fertilizer amendment at Bunda College, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.54 The effects of organic manure on rice (*Oryza sativa* L) grain yield

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A trial aimed at evaluating cattle manure and rice bran as sources of nutrients for rice production was conducted under irrigation at Lifuwu Irrigation Scheme, 28 km east of Salima headquarters from July to December, 2013. Seven treatments replicated three times were planted consisting of :T1 (control); T2- cattle manure at 25.6 kg N /ha; T3- cattle manure + half recommended fertilizer rate; T4- rice bran at 30.4 kg N/ha; T5- rice bran +half recommended fertilizer rate; T6-half recommended fertilizer rate (60 kg N/ha +12 kg P₂O₅ + 66 kg K₂O /ha; and T7- full fertilizer rate (120 kg N /ha + 25 kg P₂O₅/ha +132 kg K₂O /ha. Treatments were compared in a randomized complete block design (RCBD). Nucleus which takes 100-120 days to mature was used as test variety. One way ANOVA was used to analyze data using Genstat Discovery, 4th Edition computer package and treatment means were separated at 5% level of significance. Results indicated significant differences ($p < 0.05$) in plant height; total number of tillers per square metre; and grain yield. T7 produced higher grain yield; number of tillers per square metre; and plant height. However, rice bran produced higher yields than the inorganic fertilizers and the control. Results demonstrated the importance and superiority of the rice bran in rice production. Cattle manure produced reasonable higher grain yields than the control. Results also demonstrated that higher grain yield can be produced by applying both organic manure and inorganic fertilizers. Overall, inorganic fertilizers produced the highest grain yield. Thus, it can be recommended that, both cattle manure and rice bran be used as sources of nutrients for rice production either alone or in combination with inorganic fertilizers.

Citation: Chipole J (2014). The effects of organic manure on rice (*Oryza sativa* L) grain yield, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.55 Effect of different nitrogen sources application on soybean crop yield and quality

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A field experiment was conducted at Bunda College's Crop and Soil Sciences Department Student Research Farm in the 2013/14 growing season to study the effects of different nutrient application on yield and quality of soybean (*Glycine max* L. Merrill). An experiment was laid out in a randomized complete block design with three replicates. The list of treatments used include Triple Super Phosphate (TSP), 23:21:0 +4S, 23:10:5 +3S+0.3 Zn, cattle manure and the control (without nutrient application). The variety of soybean planted was Solitaire. Analysis of variance (ANOVA) was done using Gen-stat statistical package (15th Edition) and Tukey test was used to separate the treatment means at 5 % level of significance. The results showed that fertilizer treatments produced results that were significantly higher ($p < 0.05$) on yield and quality of soybean than the control. The treatment of 23:21:0 +4S produced 66%, 25% and 17% more grain protein, grain yield and seed weight respectively than the control treatment. TSP produced 35% more grain fat content than the control treatment and 23:10:5 +3S+0.3 Zn produced 28% more biomass yield than the control treatment. Therefore, it can be concluded that application of nutrient from both organic and inorganic fertilizers such as cattle manure, TSP, 23:21:0 +4S and 23:10:5 +3S+0.3 Zn led to higher yields and quality of soybean and therefore should be encouraged. It is recommended that similar studies should be done with different soil types.

Citation: Kanseka C (2015). Effect of different nitrogen sources application on soybean crop yield and quality. Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi.

B11.56 Assessment of the uptake of calcium and magnesium by maize (*Zea mays*) after application of 23:10:5+6S+1.0Zn or 23:21:0+4S as basal dressing fertilizers

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A study was conducted at Bunda College and Soil Sciences Student Research Farm during the 2011/12 crop season. The aim of the study was to assess the uptake of calcium and magnesium by maize (*Zea mays*) after application of 23:10:5+6S+1.0Zn or 23:21:0+4S as basal dressing fertilizers using urea as top dressing fertilizer. There were three rates of fertilizers, 0 bag, 1 bag and 2 bags for both potassic and non potassic basal dressing fertilizers which were followed by top dressing with 3 bags of Urea in treatments where 2 bags of basal fertilizer were applied. The treatments were laid out in the randomized complete block design (RCBD). Plant samples for analysis were taken following growth phases; vegetative phase (shoot stage 28 days after planting), prior to tasseling (50 days after planting) and reproductive phases (64 days after planting thus at earleaf stage). The results of the experiment showed that the potassic fertilizer consistently depressed the calcium (Ca) and magnesium (Mg) uptake by maize at all growth stages, compared to the non-potassic fertilizer. The potassic fertilizer also enhanced maize grain yield more than the non-potassic fertilizer at the rate of 2 bags of fertilizer per hectare, this is despite the fact that it depressed calcium and magnesium uptake

Citation: Mtalimanja P.K, (2013). Assessment of the uptake of calcium and magnesium by maize (*Zea mays*) after application of 23:10:5+6S+1.0Zn or 23:21:0+4S as basal dressing fertilizers, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.57 Maize response to fertilizer application with or without tobacco manure

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The price of inorganic fertilizers used by smallholder farmers for maize production has increased by 57% percentage during the 2011/12 growing season from previous season. This has renewed interest in alternative sources of inorganic fertilizers for maize production. A field experiment therefore, was conducted at Bunda College, Crop and Soil Science Student Research Farm during the 2011/12 growing season to investigate the response of maize yield to fertilizer application with and without the application of tobacco manure. This was in order to determine the substitution value of application of one rate of tobacco manure and fertilizer which will be affordable and convenient to smallholder farmers. Treatments consisted two levels of tobacco manure (0 and 2 t/ha) and five levels of inorganic fertilizer (23:21:0+4S) of 0, 100, 200, 300 and 400 kg/ha. The treatments were laid in a Randomized Complete Block Design (RCBD) replicated three times. Results showed that a combination of 100 kg of 23:21:0+4S and 2 ton/ha of tobacco manure gave the highest yield of 2887 kg/ha and optimized resources required for production.

Citation: Abraham A (2013). Maize response to fertilizer application with or without tobacco manure, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.58 Assessment of nutrient competition and requirement in maize (*Zea mays*)/soybean (*Glycine max* L) intercropping

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The study was conducted at Bunda College Students' Research Farm in the 2013/2014 growing season. It was aimed at assessing the yield of maize and soybean in intercropping, the influence of nutrient application on competitive ability of soybean and maize for nutrient uptake and the use and determining nutrient requirement for maize and soybean in an intercropping system. The experiment was laid out in a split plot design and replicated thrice. It had two main treatments and four sub treatments. Main treatments included sole cropping of both crops and an intercrop of the two and the sub treatments were different rates of nitrogen which included 92, 46, 23 and 0 kg/ha in maize and 30, 15, 7.5 and 0 kg/ha in soybean. A number of competitive indices which include Land Equivalent Ratio (LER), Relative Crowding Coefficient (K), Monetary Advantage Index (MAI) and the Relative yield of the dry matter (RDY), nitrogen (RNY) and phosphorus (RPY) were used to assess the competition. The results showed that intercropping produced a higher combined yield as compared to sole cropping of both crops. Amongst the various levels of N, 92 kg N/ha and 30 kg N/ha of maize and soybean respectively produced more yield of both crops than the rest of the rates. The maize yield obtained from a treatment of 92 kg N/ha was 30.5% and 78.8% higher than that obtained from 46 kg N/ha and 0 kg N/ha respectively. In soybean, plots with 30kg N/ha produced 18.2% higher yield than that with 0 kg N/ha. The LER indicated yield advantages ranging from 33% (LER =1.33) to 46% (LER =1.46).

The K value showed that maize dominated in the use of resources in the intercrop and in the plots with 0kg N/ha showed that introducing soybean in maize causes a decrease in yield ($K=0.15$). Monetary advantage Index (MAI) also showed an advantage of intercropping over sole cropping. Nitrogen and phosphorus uptake was higher in maize than in soybean at all levels of N showing that maize has a relatively higher N demand than soybean. With the outcomes of the competitive indices used in this investigation it can be concluded that it is advantageous to grow maize and soybean as intercrops as the practices seen to optimize resource use. It is recommended that similar studies should be done in different agro-ecological zones.

Citation: Masanjala G, (2015). Assessment of nutrient competition and requirement in maize (*Zea mays*)/soybean (*Glycine max L*) intercropping, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.59 Effect of lime and phosphorus on growth on some nutrients uptake by soybean plants

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A greenhouse experiment was conducted to study the effect of lime and phosphorus on soybean growth and its uptake of nitrogen, phosphorus, calcium and magnesium. Acid soil from Mzuzu was used. Three levels of lime (5, 10 and 15 g/2kg soil) and three phosphorus levels (0.5, 1 and 1.5/2 kg soil) were applied. Results showed that high level of lime cause a decrease in plant height, number of leaves, and dry matter yield. An increase in the dry matter yield was observed with phosphorus additions at each level of lime applications. There is a slight decrease in nitrogen uptake with increase phosphorus and lime application. On the other hand, phosphorus uptake has increased with phosphorus application. Available phosphorus in the soil after harvesting and therefore higher amounts of phosphorus uptake by soybean plants was observed in the treatment of 10 g/pot lime and 1.5 g/pot potassium phosphate. The slight decrease in the soil pH after harvesting was due to short time of lime reactions with soil acidity. It is recommended to repeat such experiments using different lime materials and different sources of phosphate fertilizers and also different soil types in order to give better advice to farmers and obtain high yields.

Citation: Ngwira S, (2004). Effect of lime and phosphorus on growth on some nutrients uptake by soybean plants, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.60 Uptake of some micronutrients as affected by the soil properties

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A greenhouse experiment was conducted at Bunda Student Research Farm in the 2005/2006 academic year to investigate the effect of soil properties and fertilizer levels on uptake of iron and copper by maize plants (*Zea mays*). Two soil series (Lilongwe and Mbabzi) were analysed before planting for some physical and chemical properties. A hybrid maize variety, NSCM 41 was grown on the two soils and in each case; the plants were subjected to four fertilizer levels. During the 50-days growing period, soil moisture was kept at the field capacity. The plants were harvested, dried and weighed, and finally analysed for iron and copper uptake. Statistical analysis showed that there was significant difference ($p<0.05$) in copper and iron uptake between the two soils at almost all level of fertilizer application. Uptake for both elements was generally higher in Mbabzi than Lilongwe. Iron uptake was increased with increase in fertilizer level for both Lilongwe and Mbabzi soil series. There was a slight increase in copper uptake for both soils at different levels of fertilizer application although the increase was not significant.

Citation: A.P Z Mtonga, (2006). Uptake of some micronutrients as affected by the soil properties, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.61 Effects of intercropping groundnuts with short and long duration pigeonpea varieties on yield and nodulation

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Doubled up legume is the technology that help to accumulate nutrients in the soil especially nitrogen which can be used by the cereal crop in the following year since in legume-cereal intercrop, the cereal does not benefit to the nitrogen fixed by the legume in the same season because the nitrogen is accumulated into the legume vegetation. Doubled up legume can be some with any other legumes which are compatible to reduce competition for high productivity. A study at Bunda College, Department of Crop and Soil Science Students' Research Farm was conducted to evaluate the nodulation and yield of long and short duration varieties of pigeonpea in a double up legume with groundnut. Five treatments were laid out in a randomized complete block design which were replicated three times.

Treatments were sole ICEAP 00040 (short duration), sole mwaiwanthualimi (long duration), sole groundnuts, groundnuts +ICEAP 00040 intercrop and groundnut and mwaiwathualimi intercrop. The results showed that there were significant differences in the weight of nodules of short and long duration pigeonpea variety. The sole and intercropped mwaiwathualimi variety had the value of 5.096 and 7.090 respectively and the sole and intercropped ICEAP variety which had 0.096 and 1.036 respectively. In groundnut there was no significant difference in weight of nodule in sole and when intercropped with either variety. There was also the same to the groundnut. Based on the findings in this study both long and short without reducing the yield of either crop.

Citation: Phiri CM (2013). Effects of intercropping groundnuts with short and long duration pigeonpea varieties on yield and nodulation, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.62 Assessment of *Tithonia diversifolia* and *Senna spectabilis* biomass nutrients for maize production

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Field study was conducted on the assessment of *Tithonia diversifolia* and *Senna spectabilis* biomass as source of nutrients for maize production compared to the recommended to inorganic fertilizer rates, was carried out at Bunda College, Department of Crop and Soil Science Students Research Farm for the second season in the 2012/13 growing season. The objectives were to assess the sole effect of incorporation of *Tithonia diversifolia* and *Senna spectabilis* biomass and in combination with inorganic fertilizer on the growth and yield components of maize. Treatment combinations were laid out in a randomized complete block design (RCBD) with four replicates. Treatment combinations to deliver a recommended fertilizer rate of 92 kg N/ha were: (i) no treatment (ii)(recommended fertilizer rate; (iii) senna biomass basal + CAN top-dress; (iv) senna biomass basal +senna top-dress; (v) senna biomass applied once; (vi) tithonia biomass basal + CAN top-dress; (vii) tithonia biomass basal +tithonia top dress; and (viii) tithonia biomass applied once. Results showed that there were no significant differences in grain yield for all treatments. Significant differences ($p \leq 0.009$) were recorded on total biomass yield, in which the recommended fertilizer rate had highest yields (8803 kg/ha), followed by tithonia *diversifolia* biomass basal + CAN top-dress (6916 kg/ha) and tithonia biomass applied aonce (7314 kg/ha). Tithonia biomass basal + tithonia top-dress produced the lowest biomass yield (4951 kg/ha) there were significant differences ($p \leq 0.076$) and ($p \leq 0.016$) in cob replacement height and cob length respectively, while plant height showed no significant differences. Overall, recommended fertilizer rate outperformed ($p \leq 0.05$) all other treatments.

Citation: Butao M (2014). Assessment of *Tithonia diversifolia* and *Senna spectabilis* biomass nutrients for maize production, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe, Malawi

B11.63 Response of two groundnut (*Arachis hypogaea*) varieties to different boron fertilizer application methods

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The study of the response of two different varieties of groundnuts (*Arachis hypogaea*) to soil and foliar method of boron application was conducted in the 2013/14 growing season at Bunda College Students Research Farm. The aim of the study was to assess the response of the two different groundnut varieties to boron application in terms of yield and yield components and to find out a recommended method of boron fertilizer application between soil and foliar methods. Varieties used were CG7 and Mkanziamakwiya. There were four boron application treatments; nil, soil, foliar and soil +foliar. The experiment was laid out in a split plot design with four replicates. Data collection included germination percentage, shelled grain yield kg/ha, days to 50 % flowering, pod length (cm), pod weight (kg), plant stand/hectare, plant height (cm) biomass (kg/ha), groundnut haulms weight (kg/ha) and haulms B- content (ppm). The results indicated that there were no significant differences in the interactions between varieties and boron application method. However, there were significant differences in haulms boron content due to the four boron application treatments. The results were not in agreement with the expected results that groundnut yield would increase with boron application.

Citation: Kanjira J, (2015). Response of two groundnut (*Arachis hypogaea*) varieties to different boron fertilizer application methods, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.64 Incidence of maize disease causing organisms under conservation agriculture**V.C Zilahowa; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi**

An experiment was conducted at Bunda College Students' Farm, Crop and Soil Science, during 2011/12 growing season. The experiment was to find the effects of conservation practices on the incidences of maize causing organisms under conservation agriculture. Treatments consisted of two practices (mulching; conservation agriculture 1, and no ridging; conservation agriculture 2) and a control (ridging; conventional cultivation) the treatments were arranged in a randomized complete block design (RCBD) with three treatments replicated four times. The treatments were ridging (conventional cultivation) mulching (conservation agriculture 1) and no-ridging (conservation agriculture 2). The overall objective of the experiment was to monitor yield and status of soil borne- pathogenic fungi under the maize based cultural systems. The specific objectives were: 1) to investigate the incidences of maize disease causing organisms under different cultivation systems, 2) to compare yield of maize crop under conventional cultivation (CC) and conservation agriculture systems. Maize variety, SC 403 was planted to all the three treatments, and data collected included grain yield, plant stand count, and plant height and canopy length. The data were analyzed using GENSTAT 2000 statistical package, and analysis of variance was used to separate the means. A baiting method by the use of fresh carrot pieces was used to look the frequencies of soil borne-maize disease causing organisms in all the soil samples collected from the treatments. Data on the growth of fungi was collected at week five as an incubation period. The results showed that the frequencies of occurrence of the soil borne disease causing pathogens were the same in all the three treatments (no-tillage, mulching and ridging). The results on grain yield showed significant differences ($p < 0.016$) in no tillage and mulching practices. The grain yield from no-tillage was higher than of the mulching treatment.

Citation: Zilahowa VC (2013). Incidence of maize disease causing organisms under conservation agriculture, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.65 Residual effects of cattle manure and mineral fertilizer on maize yield and soil quality**N Bilima; Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O Box 219, Lilongwe, Malawi**

The residual effect of cattle manure and NPK granular compound fertilizer on maize yield were investigated on a site where soil reaction was acidic ($pH \leq 5.7$), mean N contents varied from 0.23% (w/w) to 0.38 % (w/w), the mean Mehlich 3 extractable P contents ranged from 21 mg/kg to 35 mg/kg, mean exchangeable K contents varied from 42 mg/kg to 66 mg/kg and mean organic matter contents ranges from 4.9% (w/w) to 5.8% (w/w). The response of maize to increasing residual effects of cattle manure was quadratic with a maximum yield obtained between an application of 3.5 t/ha and 10 t/ha cattle manure, while the response to increasing levels of inorganic fertilizer was linear. The residual effects of cattle manure on cob length were statistically significant at 5% level of probability level whereas the residual effects due to the interactions between cattle manure and compound fertilizer were not, within limits of experimental error, statistically significant. The residual effects of each of the external inputs on plant height was statistically significant at 5 percent probability level. The residual effects of cattle manure x compound fertilizer 23:10:5 + (3S and 1Zn) interactions were also significant at 5 percent probability levels. Because plant height is an important index of plant nutrients use for vegetative growth, it has been concluded that there were significant differences in the yield of the test crop due to the treatment effects and that, this particular soil had adequate levels of plant nutrients as complementary inputs. It is also recommended that the long-term experiment be used to determine how long the residual effects last before need arise for economic applications of both mineral fertilizers and organic materials.

Citation: Bilima N (2013). Residual effects of cattle manure and mineral fertilizer on maize yield and soil quality, Bachelor of Science Report, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, Lilongwe Malawi

B11.66 Maize response to fertilizer rates and placement method of pigeonpea residues**F.D Sanga; University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi**

Tree legumes such as pigeon peas (*Cajanus cajan*) are good candidates for agroforestry. In addition to their symbiotic relationship with *Rhizobium* spp. which fix nitrogen into the soil, pigeon pea seeds also act as an important source of food. Smallholder use stems as source of fuel wood and the leaves unfortunately are wasted and only those leaves that drop onto the ground are responsible for nutrient recycling. A study was conducted to find out the best option of utilizing the leaf litter in a rotation system of pigeon pea with maize. The leaves were placed on the surface in zero tillage farming method and in other plots they were incorporated into the soil.

The trial was conducted at Bunda College of Agriculture, Crop and Soil Science Department Student Research Farm during the 2007/2008 growing season. The result showed that the interaction of residues and fertilizer rate had no significant effect on yield ($p>0.01$) but had an effect on the kernels per ear ($p<0.01$) and cob length ($p<0.01$) at significant level of 5%. The results also showed that there was a significant difference in the yield when different rates of fertilizer used ($p<0.007$) and that the biomass was highly significant ($p<0.01$) at significant level of 0.05. The results also showed that placement method of pigeonpea residue on maize yield was significant ($p<0.042$) and biomass was also significant ($p<0.015$).

Citation: Sanga F.D, (2009). Maize response to fertilizer rates and placement method of pigeonpea residues Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

B11.67 Assessing soybean (*Glycine max*) varieties as trap crop against *Striga asiatica* (witchweed) in maize

A.C.Y Maulawo; University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi

Studies were conducted at Chitedze Agricultural Research Station to screen amongst several soybean (*Glycine max*) to test their effectiveness as trap crops for *Striga asiatica* all under artificial infestation. The experiment was aimed at soybean variety or varieties that effectively include suicidal germination of *Striga asiatica*. Higher yields of maize were obtained where Bossier and 427/5/7 were planted. The moderate yields were obtained where TG x 1681-3F, TG x 1649-11F and TG x 1448-2E were grown while the least yields were obtained where Kudu were used as trap crops. This can be translated that those with higher yields are better varieties compared to those with the lowest yields. The results could be used as preliminary basis for choosing varieties for rotation and in assembling a management package for *Striga asiatica* to ensure reduced risks to farmers.

Citation: Maulawo A.C.Y, (2003). Assessing soybean (*Glycine max*) varieties as trap crop against *Striga asiatica* (witchweed) in maize, Bachelor of Science Report, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi

Part 12: List of Publications Without Abstracts

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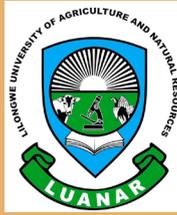
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Malawi Soil Health Consortium

The Malawi Soil Health Consortium

The Malawi Soil Health Consortium was formed in 2013 under the leadership of Lilongwe University of Agriculture and Natural Resources, Bunda Campus with funding from the Soil Health Program of AGRA. The International Plant Nutrition Institute provided technical backstopping to the consortium. The objectives of the consortium were to:

- i. To improve access by smallholder farmers and other stakeholders to ISFM innovations
- ii. Harmonize agricultural approaches, protocols and recommendations to reveal the most effective agricultural technologies for various regions and crops
- iii. Reduce duplication of effort through consolidation and improvement of access to available agricultural innovations

The consortium has a national stakeholder forum that draws representation from national and international research institutions, universities, plant and soil laboratories, agricultural extension departments, policy makers, farmer organizations, development agencies and the input-output market players (fertilizer and seed companies).



Ministry of Agriculture , Irrigation and Water
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