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# Fodder production, yield and nodulation of some elite cowpea (*Vigna unguiculata* [L.] Walp.) lines in central Malawi

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**Cowpea is (*Vigna unguiculata* [L.] Walp.) is multipurpose legume grown for its edible grain and leaves and may be used as green manure or animal feed. The shoot biomass or fodder production of cowpea nodulation and effectiveness are seldomly considered in screening and release studies, yet such information is important for the use of the crop. A field study was therefore conducted Bunda College, (14° 35 S'; 33° 50 E', Lilongwe, Malawi in the 2012 to 2013 cropping season to evaluate the performance of eight elite cowpea lines originally from the International Institute of Tropical Agriculture (IITA), compared to two released varieties (Sudan 1 and IT82E-16) for fodder production, nodulation and grain yield and yield components in a randomized complete block design. The results showed there were significant differences (P<0.05) in grain yield (1.1 to 3.1 t ha$^{-1}$), fodder (1.1 to 3.0 tha$^{-1}$) plant height at flowering (25 to 67 cm), pods m$^{-2}$ (55 to 224), seeds per pod (10-14), cumulative leaf fall (0.9 to 1.8 tha-1) and nodules per plant (9 to 21). There were no significant differences on % nodule effectiveness (mean 95%) and canopy width at flowering (mean 51 cm). The elite line IT98K-205-8 produced the highest grain yield of 3,085 kg/ha followed by the variety Sudan 1 with 3,065 kg/ha and then elite line IT98K-205-9, which produced 2,763 kg ha$^{-1}$. The lowest yielding elite line was IT93K-693-2 which gave 1,092 kg ha$^{-1}$ of grain. Cumulative leaf fall accounted 31 to 94% of total fodder dry matter. Sudan 1 also had the highest nodules per plant (22) followed by IT82E-16 and IT99K1060. Estimated fodder N content was 2.4% giving 24 to 72 kg ha$^{-1}$ as potential N in fodder. Although these lines were not selected as dual purpose, the results show opportunity for selecting dual purpose lines through evaluating for biomass. The released variety Sudan 1 notably had high grain yield, number of nodules and pods per plant.**

**Key words:** Cowpea nodulation, biomass production, natural leaf fall.

## INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is an edible legume crop grown for its grain while leaves may be used as a vegetable, green manure or animal feed or as a silage crop. Cowpea grain contains 24 to 32% protein (Neil et al., 1992), and the crop is adaptable to drought (Hall, 2004). In Malawi cowpeas are important in the dry areas

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where legumes such as beans (*Phaseolus vulgaris* L.) do not do well (MoAFS, 2012). In the 2011 to 2012 season average cowpea yields were 348 kg ha$^{-1}$, against potential yields of 2000 to 2500 kg ha$^{-1}$ (MoAFS, 2012). Like many legumes, cowpeas are complimentary to cereals and other non-legume crops through fixation of atmospheric nitrogen in a process called biological N fixation (Nyemba and Dakora, 2010; Snapp, 1998; Ojiem et al., 2000; Myaka et al., 2006). In Burkina Faso, Bado et al. (2006) reported that cowpeas accumulated 2.5 to 3.4 t ha$^{-1}$ of stover containing 50 to 115 kg ha$^{-1}$ N of which 52 to 56% was derived from the atmosphere. In soils low in phosphorus, the roots of cowpea develop effective mycorrhizal association improving the soil's available phosphorus content (Valenzuela and Smith, 2002). The roots and fallen leaves of cowpea make significant differences to subsequent cereal yields (Carsky and Vanlauwe, 2002; Bado et al., 2006). The crop forms an excellent crop cover for suppressing weeds while at the same time providing soil erosion control (Valenzuela and Smith, 2002). Cowpeas are also considered suitable as cover crops in conservation agriculture systems (Mupangwa et al., 2012). Like many legumes, cowpeas are also important in the rotation or intercropping cereal crops where cowpea serves as a trap crop by helping to reduce the seed bank of striga spp, parasitic weed of cereals (Berner et al., 1996; Kabambe et al., 2005; Carsky et al., 1994). In Malawi, several efforts have been undertaken to promote legumes for the above reasons (Ngwira et al., 2012; ICRISAT/MAI, 2000), including the national Farm Input Subsidy Programme (FISP), which included seeds of grain legumes (MoAFS, 2007; MoAIWD, 2012).

From the foregoing, it is evident that most of the non-grain uses of cowpea are related to its above ground biomass and its nitrogen fixation. Thus in order for cropping systems planners to take full advantage of the same, it is important that information on biomass and nodulation is known for pre-release or released varieties. Many screening programs do not evaluate for this (Mazuma et al., 2008; Kabambe et al., 2014). The objective of this study was to evaluate eight elite cowpea lines in an on-going cowpea project supported by the McKnight Foundation of USA for yielding ability, nodule formation and effectiveness and biomass production.

## MATERIALS AND METHODS

### Study location, treatments, experimental design and plots sizes

This study was conducted at Bunda College Crop and Soil Sciences Student's Research Farm during the 2011/2012 growing season. The site is 1158 m above sea level, latitude 14° 35 S' and longitude 33° 50 E'. The soil type varies from clay loam to sandy loam textural classes with medium fertility. The mean annual rainfall is approximately 1031 mm with coefficient of variation (cv %) of 16.6% indicating adequate reliability of total rainfall (Jones and Kanyama, 1975). The total rainfall l for the season under review (2011 to 2012) was 1001.7 mm. The crop received rainfall amounting to 816.5 mm between January and mid-April 2012 which was 81.5% of the season's total rainfall. This was adequate rainfall for cowpea production and distribution was also good throughout the crop growing period.

The study evaluated eight ex-International Institute of Tropical Agriculture (IITA) elite cowpea lines in comparison to two released varieties Sudan 1 and IT82E-16, out of only three released cowpea varieties in Malawi (Mviha et al., 2011). Table 1 provides a list of the treatments and their descriptions. The lines were in advanced stages of evaluation by a cowpea project at Lilongwe University of Agriculture and Natural Resources, supported by the McKnight Foundation of USA. A randomized complete block design with three replications was used. Plots comprised of 4 ridges x 4.0 m long x 0.75 m apart. The net plot areas was comprised the middle 2 ridges x 4.0 m long x 0.75 m (area = 6 m$^2$). Two seeds of cowpea were planted per station, spaced at 20 cm apart. The expected plant count was 13.3 plants m$^{-2}$ or 133,000 ha$^{-1}$. There was no fertilizer of any kind applied to the plots. All these agronomic practices were in line with current recommendations (MoAFS, 2012). The experiment was planted on 3rd January 2012. Nodulation was based on resident bacteria in the soil, not supplementary inoculation.

### Data recording and collection

Data was collected and reported on the following parameters: Plant count at harvest, plant biomass, pods per plant, 100 seed weight, number of nodules, effective nodules, canopy width and plant height. Data on plant counts and grain yield were recorded from the net plot area of 6.0 m$^2$. Recorded grain yield was converted to 12% storage moisture. Pods per plant were recorded from the plants harvested and expressed as pods m$^{-2}$. Cowpea plant biomass or fodder was the sum of periodic cowpea leaf fall collections and above ground fodder from plants at harvest. Dry leaves from free fall were collected from litter traps covering an area of 2 m x 0.75 m (1.5 m$^2$) in the net plot area. The traps were simply plastic sheet laid in between plant rows at 2 weeks after planting. Three collections were made at 8, 11 and 14 weeks after planting (WAP) and oven dried at 72°C for 48 h (Koide et al., 2000). Fodder at harvest was taken from all above ground plant matter from net plot area and oven-dried as above. Harvesting was done in mid-April after 100 days from planting (DAP). Average N content of fodder was determined by taking sub-samples of combined fodder from leaf fall and standing plants in all plots in each of the three replications. The sample analyzed for N using the Kjeldhal method as modified by Anderson and Ingram (1993).

Canopy width and plant height (cm) was an average five readings within the net plot. Canopy width was recorded by as linear measurement of the width of the canopy at 49 DAP (mid-flowering) only. A maximum distance of 0.75 m reflected full canopy closure, as this was the row width. Plant height was linear measurement from base to tallest upright growing point (tip) and was taken at 49 days after planting only. Number of nodules per plant was recorded as an average from four plants that were dug out per treatment and nodules found on the plants were counted. This was done when the cowpeas had just started flowering and sampling was done on borders of ridges because it was destructive sampling. Nodule effectiveness was assessed by looking at the inside color of nodules. Ten nodules from each variety/elite line were sampled, opened and color-examined. The ten nodules were randomly collected from the four plants dug out in a treatment. Those nodules with red/brown color were deemed effective and those with different colors such as green or white (lacking in leghemoglobin) were considered not effective for nitrogen fixation according to Gobat et al. (2004). Harvest index was calculated by as: [total grain yield per hectare/(total above ground biomass per

**Table 1.** Treatment descriptions.

| Entry code | Name* | Description of seed | Days to maturity | Leaf type | Type: released or elite |
|---|---|---|---|---|---|
| 3 | IT 99K-491-7 | Medium Unit, black eye | 79 | Broad | Elite |
| 5 | IT98K-503-1 | Medium white, brown eye | 79 | Broad | Elite |
| 24 | IT99-1060 | Medium brown | 77 | Broad | Elite |
| 31 | IT98K-205-9 | Medium white, black eye | 79 | Broad | Elite |
| 33 | IT98K-205-8 | Medium white, black eye | 79 | Broad | Elite |
| 35 | IT99K-1245 | Medium white, black eye, segregating | 74 | Broad | Elite |
| 45 | IT95-1090-12 | Medium brown | 78 | Narrow | Elite |
| 47 | IT93K-693-2 | Medium brown, shrinkled | 74 | Broad | Elite |
| 51 | Sudan 1 | Small round, cream | 69 | Broad | Released |
| 52 | IT82E-16 | Small round, pink | 70 | Narrow | Released |

*all 'IT…' entries are from IITA. Source of Sudan 1 not well known.

**Table 2.** Performance of elite lines on plant height, grain yield and yield components and harvest indices.

| Cowpea entry | Plant height (cm) | Pods ($m^{-2}$) | Pod length (cm) | Seeds no./pod | 100 seed weight (g) | Grain Yield kg $ha^{-1}$ |
|---|---|---|---|---|---|---|
| IT99K-491-7 | 54.2 | 101 | 11.40 | 9.67 | 12.47 | 1496 |
| IT98K-503-1 | 52.6 | 105 | 10.08 | 8.00 | 12.78 | 1588 |
| IT99K-1060 | 36.0 | 146 | 12.18 | 11.00 | 12.31 | 2119 |
| IT98K-205-9 | 55.9 | 214 | 12.66 | 10.33 | 11.88 | 2713 |
| IT98K-205-8 | 29.2 | 224 | 13.51 | 13.88 | 10.97 | 3085 |
| IT99K-1245 | 33.7 | 60 | 11.94 | 9.67 | 12.81 | 1265 |
| IT95-1090-12 | 67.1 | 55 | 10.06 | 8.67 | 11.28 | 1176 |
| IT93K-693-2 | 25.7 | 77 | 11.81 | 10.67 | 13.36 | 1097 |
| Sudan 1 | 25.7 | 179 | 15.81 | 14.33 | 9.44 | 3065 |
| IT82E-16 | 67.2 | 160 | 11.68 | 10.00 | 14.43 | 2662 |
| Mean | 49.0 | 132 | 12.06 | 10.57 | 12.17 | 2117 |
| LSD (0.05) | 23.5 | 85.63 | 1.70 | 1.524 | 2.12 | 928.6 |
| F Prob. | 0.004 | 0.003 | 0.049 | 0.001 | 0.008 | <0.001 |

hectare)] that is (above ground biomass + grain yield + pod weights).

#### Data analysis and mean comparison

Data were analyzed using the analysis of variance and regression procedure using Genstat 16 statistical package, and means were separated by Least Significant Difference (LSD) at 5%.

## RESULTS AND DISCUSSION

### Cowpea growth, yield and yield components

The analysis of variance showed that there were significant treatment differences (<0.05) on plant height, podsm$^{-2}$, pod length, seeds per pod, 100 seed weight and grain yield (Table 2). There were no significant entry effects on harvest count (mean 130,556 = plants ha$^{-1}$), harvest index (mean = 0.52) and canopy width (mean = 50.7 cm). The absence of significant difference on canopy width and harvest index is surprising considering that there were significant yield differences. The observed variability in plant height is expected as these are distinct lines with varying growth habits. Valenzuela and Smith (2002) noted that cowpea grows rapidly, reaching a height of 48 to 61 cm when grown under favorable conditions. On seed weight, the seed sizes of all entries was generally small in comparison to sizes of up 21 g/100 seeds reported by Omokonye et al. (2003).

On grain yield, the released variety Sudan 1 gave joint highest yield with the elite line IT98K-205-8 of about 3.0 t ha$^{-1}$. Only one other elite entry yielded above 2.5 tha$^{-1}$, along with released IT82E-16. The high yielding entries also had higher pods m$^{-2}$. The high yield of Sudan 1 was associated with long pod length, seed weight and plant

**Table 3.** Fodder biomass, cumulative leaf fall and total fodder biomass of cowpea elite lines/varieties.

| Cowpea elite lines | Leaf fall 1 kg/ha 8 WAP* | Leaf fall 2 kg/ha 11 WAP | Leaf fall 3 kg/ha 14 WAP | Cumulative Leaf fall kg/ha | Total Fodder (kg/ha) | Cumulative leaf fall as % of total fodder |
|---|---|---|---|---|---|---|
| IT99K-491-7 | 597 | **558** | 397 | 1553 | 3021 | 51 |
| IT98K-503-1 | 605 | 283 | 253 | 1141 | 2041 | 56 |
| IT99K-1060 | 331 | 112 | 304 | 747 | 2046 | 37 |
| IT98K-205-9 | 455 | 383 | 234 | 1072 | 1530 | 70 |
| IT98K-205-8 | 262 | 166 | 129 | 556 | 1822 | 31 |
| IT99K-1245 | 388 | 398 | 243 | 1029 | 1782 | 58 |
| IT95K-1090-12 | 581 | 457 | 143 | 1180 | 1475 | 80 |
| IT93K-693-2 | 808 | 220 | 64 | 1092 | 1156 | 94 |
| Sudan 1 | 1115 | 472 | 246 | 1834 | 1931 | 94 |
| IT82E-16 | 337 | 316 | 244 | 897 | 1502 | 60 |
| Mean | 548 | 337 | 226 | 1110 | 1821 | - |
| LSD (0.05) | 352.3 | 358.3 | 222.6 | 613.5 | 936.3 | - |
| F Prob. | 0.002 | 0.034 | 0.194 | 0.018 | 0.034 | - |

*WAP = weeks after planting.

height, but this was not true for the other entries with high grain yield. Only two of the elite lines compared well with potential yields of 2.0 to 2.5 tha$^{-1}$ for Malawi (Mazuma et al., 2008; MoAFS, 2012; Kabambe et al., 2014). Mazuma et al. (2008) also reported that Sudan 1 and IT82E-16 were amongst high yielding entries giving yields of 1789 and 1509 kgha$^{-1}$ respectively. Results are also comparable to those of Akande and Balogun (2009) who reported highest cowpea yields of 1737 kg ha$^{-1}$ in a multi-locational programme in Nigeria. However, average grain yield in this study was much higher than the average yield of 750 to 1000 kg ha$^{-1}$ in Nigeria (Omokanye et al., 2003; Kamara et al., 2008).

## Leaf fall and total fodder yield

The results of leaf fall show significant entry differences for leaf fall at 8 WAP, 11 WAP, cumulative leaf fall and total biomass but not for leaf fall 3 (Table 3). The results show that Sudan 1 and IT93K-693-2 shed most leaves at leaf fall 1 while IT99K-491-7 shed most leaves at leaf fall 2. Leaf fall declined with sampling time. It is therefore likely that some of the fallen leaves could contribute to improved fertility status and yield in cropping systems involving intercropping with long season crop types. However, early leaf may not be compatible with systems aiming to use residues for animal feed or as mulch to prevent evaporation in subsequent dry months.

The highest cumulative leaf fall (1834 kgha$^{-1}$) came from Sudan 1, followed by 1553 kg ha$^{-1}$ from entry IT99K-491-7. Notably, for Sudan 1 the cumulative leaf fall was 94 % of total biomass, while for the later this was 51 %. The highest fodder biomass was recorded from IT99K-491-7 (3021 kg ha$^{-1}$) followed by IT98K-503-1, IT99K1060 and Sudan 1 (2041-1931 kg ha$^{-1}$). These fodder yields are in same range as reported by Omokanye et al. (2003) and Bado et al. (2006). Of the entries in the study only two (IT99K-1060 and Sudan 1) gave yield and fodder of about 2000 kg and could be considered dual purpose. The average N content of the stover was 2.4%, thus giving potential contributions of 24 to 72 kg ha$^{-1}$ nitrogen. The N content compares well with 2.5% reported in pigeon pea (ICRSAT/MAI 2000), but below 3.6% reported by Bado et al. (2006) in cowpeas. In general a minimal green manure rate of 2.0 t ha$^{-1}$ is considered as agronomic threshold (ICRISAT/MAI 2000). While these entries are not purpose-bred, the results show the potential benefit of screening for the same at later stages of research programs to enrich uses of released varieties.

## Nodulation

There were significant treatment differences on number of nodules per plant (Table 4), but not on % effective nodules (mean = 95.0%). The highest nodule number came from Sudan 1 (21.7 nodules/plant), followed by IT8282E-16 (18.9), IT95-1090-12 (14.42) and 1T99K-1060 (14.0) Only two entries (Sudan 1 and IT99K-1060) appear to give grain and forage yields of about 2 tha$^{-1}$ or more and high nodule numbers. These results concur with the ranges of 3-21 nodules per plant reported by Bhuvaneswari et al. (1998). Ndor et al. (2012) showed that nodules per plant in cowpeas increased from 20 to 32 when P application was raised from 0 to 40 kg ha$^{-1}$ P. The authors reported cowpeas yield increase from about

**Table 4.** Nodulation cowpea elite lines and varieties.

| Cowpea elite lines / Varieties | Average number of Nodules/ Plant |
|---|---|
| IT99K-491-7 | 10.42 |
| IT98K-503-1 | 13.17 |
| IT99-1060 | 14.00 |
| IT98K-205-9 | 9.00 |
| IT98K-205-8 | 9.57 |
| IT99K-1245 | 9.08 |
| IT95-1090-12 | 14.42 |
| IT93K-693-2 | 8.33 |
| Sudan 1 | 21.75 |
| IT82E-16 | 18.92 |
| Mean | 12.88 |
| LSD (0.05) | 7.09 |
| F Prob. | 0.01 |

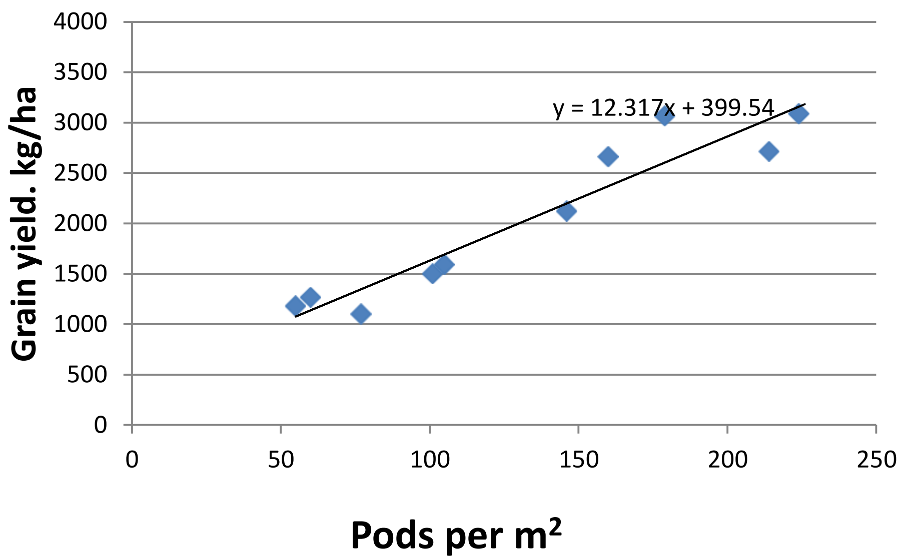


**Figure 1.** Relationship between podm$^{-2}$ and grain yield.

1.0 to 1.5 t ha$^{-1}$ with associated with the same P application rates.

## General discussion

A number of regression relationships were explored, and only the grain yield and pod m$^{-2}$ yielded a significant regression (Figure 1). This is a fitting result since pods m$^{-2}$ is an aggregate expression of many yield components and management factors including pest control. The results from this study have also shown that elite lines IT99K-491-7, IT98K-503-1 and IT99-1060 were outstanding fodder producers at over 2 t ha $^{-1}$. The best fodder yield of 3 t ha$^{-1}$ gave 1.8 t ha$^{-1}$ grain yield. The results show that various combinations of biomass or grain yield options exist and it might be good for researchers to release a range of lines to provide for options in use.

## Conflict of Interest

The authors have not declared any conflict of interest.


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**REFERENCES**

Akande SR, Balogun MO (2009). Multi-locational evaluation of cowpea grain yield and other reproductive characters in the forest and Southern Guinea savanna agro-ecologies of Nigeria. Electronic J. Environ. Agric. Food Chem. 8(7):526-533.

Anderson JM, Ingram JSI (1993). Tropical soil biology and fertility. A Handbook of Methods. CABI, UK.

Bado BV, Bationo A, Cescas MP (2006). Assessment of cowpea and groundnut contributions to soil fertility and succeeding sorghum yields in the Guinean savannah zone of Burkina Faso (West Africa). Biol. Fert. Soils. 43:171-176.

Berner DA, Carsky R, Dashiell K, Kling J, Manyong A (1996). A land management based approach to integrated *Striga hermonthica* control in Sub-saharan Africa. Outlook on Agriculture. 25:157-164.

Bhuvaneswari TY, Lesniak AP, Bauer WD (1998). Efficiency of nodule initiation in cowpea and soybean. Plant Physiol. 86:1210-1215.

Carsky RJ, Singh L, Ndikawa R (1994). Suppression of *Striga hermonthica* by means of a cowpea intercrop. Experimental Agric. 30:349-359.

Carsky RJ, Vanlauwe B (2002). Cowpea Rotation as a Resource Management Technology for Savannah cereal based systems in West Africa; Proceedings of the world cowpea Research conference 111. International Institute of Tropical Africa, Ibadan, Nigeria.

Gobat JM, Aragno M, Matthey W (2004). The Living Soil. Fundamentals of Soil Science and Soil Biology. Science Publishers, Inc. Plymouth, United Kingdom.

Hall AE (2004). Breeding for adaptation to drought and heat in cowpea. Europ. J. Agron. 21:447-454.

ICRISAT/MAI (2000). Cost-effective soil fertility management options for smallholder farmers in Malawi. Bulawayo, Zimbabwe: ICRISAT; and Lilongwe, Malawi: Ministry of Agriculture and Irrigation. P. 21.

Jones MJ, Kanyama GY (1975). Some Physical and Chemical Properties of the Soils of Bunda College farm. Res. Bull. Bunda College Agric. 6:1-14.

Kabambe VH, Mazuma EDL, Bokosi J, Kazila E (2014). Release of cowpea line IT99K-494-6 for yield and resistance to the parasitic weed *Alectra vogelii* (Benth) in Malawi. Afr. J. Plant Sci. 8(4):196-203.

Kabambe VH, Nambuzi SC, Kauwa AE (2005). Role of cowpea and silverleaf intercropping in suppression of witchweed (Striga asiatica L. Kuntze) in maize in Malawi. In: ACL Safalaoh, GP Gowela, H Mtethiwa (eds). Proceedings of the 2nd Bunda College Research Dissemination Conference. Lilongwe. pp. 22-27.

Kamara AY, Chikoye D, Ekeleme F, Omoigui LO, Dugje IY (2003). Field performance of improved cowpea varieties under conditions of natural infestation by the parasitic weed *Striga gesnerioides.* Int. J. Pest Manage. 43(3):189-195.

Koide RT, Robichaux RH, Morse R, Smith C (2000). Plant water status, hydraulic resistance and capacitance. In: Peacy RW, Ehleinger J, Rooney HA, Rundel PW (eds). Plant Ecology, Field Methods and Instruments. Kluwer Academic Publishers. Dordrecht, Netherlands. pp. 161-183.

Mazuma EDL, Muyombe MC, Andersiki RB, Pungulani L (2008). Screening cowpea varieties/lines for predominant cowpea diseases and high yielding ability at Chitedze Agricultural Research Station, Lilongwe. Annual Report, Oil Seed and Other Grain legumes, Chitedze Research Station.

MoAFS (Ministry of Agriculture and Food Security) (2012). Guide to Agricultural Production in Malawi, Ministry of Agriculture and Food Security, Lilongwe, Malawi. P. 335.

MoAIWD (Ministry of Agriculture, Irrigation and Water Development) (2012). 2010/11 Annual Statistical Bulletin. Ministry of Agriculture, Irrigation and Water Development, Department of Agricultural Planning Services, Lilongwe, Malawi. P. 288.

Ministry of Agriculture and Food Security (MoAFS) (2007). Annual Agricultural Statistical Bulletin. Planning Division. Government of Malawi. Lilongwe, Malawi. P. 116.

Mupangwa W, Tromlow S, Wlaker S (2012). Reduced tillage, mulching and rotational effects on maize (*Zea mays* L.) cowpea (*Vigna unguiculata* [Walp] L and sorghum under semi-arid conditions. Field Crops Res. 132:139-148.

Mviha PJZ, Mtukuso AP, Banda MHP (2011). A catalogue of agricultural technologies used by farmers in Malawi. Department of Agricultural Research Services, Lilongwe, Malawi. P. 40.

Myaka FM, Sakala WD, Adu-Gyamfi JJ, Kamalongo D, Ngwira A, Odgaard R, Nielsen NE, Høgh-Jensen H (2006). Yields and accumulations of N and P in farmer-managed intercrops of maize-pigeonpea in semi-arid Africa. Plant Soil. 285:207-220.

Ndor E, Dauda NS, Abimuku EO, Azagaku DE, Anzaku H (2012). Effect of phosphorus Fertilizer and spacing on growth, nodulation count and yield of cowpea (*Vigna unguiculata* [L.] Walp in Southern Guinea Savanna agroecological zone, Nigeria. Asian J. Agric. Sci. 4(4):254-257.

Ngwira AR, Kabambe VH, Kambauwa G, Mhango WG, Mwale CD, Chimphero L, Chimbizi A, Mapfumo F (2012). Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi. Afr. J. Agric. Res. 7(6):918-928.

Nyemba RC, Dakora FD (2010). Evaluating $N_2$ fixation by food grain legumes in farmers' fields in three agro-ecological zones of Zambia, using N15 natural abundance. Bio. Fertl. Soils. 46:461-470.

Neil FS, Siebrits FK, Hayes JP (1992). Studies on the nutritive value of cowpes (*Vigna unguiculata*). South Afr. J. Animal Sci. 22(5):157-160.

Ojiem JO, Vanlauwe B, de Ridder N, Giller KE (2000). Niche-based assessment of contribution of legumes to nitrogen economy of Western Kenya smallholder farm. Plant Soil. 292:119-135.

Omokonye AT, Onifade OS, Amodu JT, Balogun RO, Fallah MS (2003). Evaluation of duopurpose cowpea (*Vigna unguiculata* [L.] Walp) varieties for grain and fodder yield at Shika in Nigeria. Tropicultura 21(1):42-46.

Snapp SS (1998). Soil nutrient status of smallholder farms in Malawi. Comm. Soil Plant Anal. 29:2571-2588.

Valenzuela H, Smith J (2002). Cowpea. Sustainable Agriculture Green Manure Crops, Aug. 2002, SA-GM-6. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/GreenManureCrops/cowpea.pdf.