Yields of Maize and Multiple Advantages of Pigeon Pea in Maize Intercropping at Bako, Western Ethiopia

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Abstract

Maize highly depletes nutrients in maize monocropping system and the situation is more serious when crop residues are continuously removed from the farmland. Consequently, the return from inorganic fertilizers application alone in the system is seasonal, requiring amendment of nutrients removed from the soil and retention of yield declined due to nutrient depletion. This experiment was executed at Bako in 2013, 2014 and 2015 main cropping seasons with the objective of evaluating the effect of branch removal of perennial pigeon pea and N level on yields of maize, on soil moisture and bulk density dynamics in maize/pigeon pea intercropping system. The treatments consisted of maize/pigeon pea intercropping in factorial combinations of four pigeon pea branch removals while leaving the upper (0, 2, 4 and 6) and five nitrogen levels (18, 41, 64, 87 and 110 kg ha^{-1}) and sole maize monoculture laid out in randomized complete block design with three replications. Main effects due to pigeon pea branch removal and N level were significant for maize dry biomass yield during 2013 and 2014 and also significant for maize grain yield throughout the experimental periods. Removal of lower branches of pigeon pea while leaving the upper 2 in maize/pigeon pea intercropping increased grain yield of maize by 8% and produced higher dry biomass yield presumably due to taller maize plants which took relatively longer days to mature. Significantly increased soil moisture and reduced soil bulk density compared to the sole maize monoculture was obtained due to removal of lower branches of pigeon pea while leaving the upper 2 in maize/pigeon pea intercropping system. Higher dry biomass yield pigeon pea can be used as feed sources during feed shortage seasons. Hence, the system increased maize productivity at reduced N level, it is recommended for its maximization of crop and land productivity in the sub-humid maize based monocropping system of Bako and similar agro ecologies.

Keywords: Intercropping, maize, mono cropping, pigeon pea

Introduction

Maize productivity in Ethiopia is currently increasing due to the release of many high yielding hybrid varieties. However, the productivity is low compared to farmers' international potential yield. This yield gap is attributed mainly due to low soil fertility, crop diseases, insect pests and soil acidity resulted from maize monocropping. The system has been most common in the sub-humid areas of western Ethiopia. CIMMYT (2010) reported that 94% of the respondent farmers from maize belt areas of Bako Tibe and Gobu Sayo districts grow maize continuously on the same plot of land. Nutrient depletion by maize in maize monocropping system is high and the situation is more serious when important plant nutrients are removed with crop residues. Consequently, the return from inorganic fertilizers application alone in the system is seasonal, requiring amendment of nutrients removed from the soil and retention of yield declined due to nutrient depletion.

The tradition of leaving degraded farm lands fallow but practice open livestock grazing aiming at improving soil fertility lead to the lowest organic matter contribution compared to the mixed crop lands (Asif *et al.,* 2014). Declining of soil fertility aggravated by wide scale continuous cultivation of maize which mines the soil nutrients remained the farmers struggling to maintain yields year after year (Snapp *et al*., 2010). Rising human consumption from crop source is dramatically increasing depends on agriculture and natural resources which raises challenges for achieving food security (Foley *et al.*, 2011). Through strategic improved crop varieties and inorganic fertilizer use, it might not be enough to feed the growing population requiring production of more food on the same amount of land (Giller *et al.*, 2006).

Cereal/legume cropping system show considerable promise in boosting productivity, helping reverse the decline in soil fertility (Dagne *et al.,* 2012) and improves dietary sources. Incorporating nitrogen fixing legumes in to maize based cropping systems has the potential to improve soil fertility and mitigate the nutrient mining of maize (Snapp and Silim, 2002). Pigeon pea in the systems with advantages of fertilizer value, dry season animal feed and seeds for human consumption (Abebe and Diriba, 2002) has the potential of reacting with iron-bond phosphate in the soil to release P (Hector and Smith, 2007).

Ethiopia with wide range of ecological suitability to pigeon pea didn't widely enter into the multiple uses from the crop. Zerihun *et al.(*2016) reported perennial pigeon pea can be used as a live-stake for climbing bean and production of finger millet as intercrop during the establishment phase. The litter fall reduces soil erosion, improves soil fertility and larger root mass contributes to improvement of soil organic matter. Faster establishment in subsequent years reduces cultivation cost when conservational agriculture is used. Therefore, the objective of this study was to evaluate the effect of branch removal of perennial pigeon pea and N level on crop yields of maize, on soil moisture and bulk density dynamics in maize/pigeon pea intercropping system at maize belt areas of Bako, western Ethiopia.

Materials and Methods

Description of the study area

The experiment was conducted on reddish-brown clay-loam Nitosols in 2013, 2014 and 2015 cropping season at Bako Agricultural Research Center, which is situated in the western part of Ethiopia at an altitude of 1650 m.a.s.l. The area has a warm-humid climate with annual minimum and maximum temperatures of 13.6 and 29.1^0 C, respectively. Long-term average annual rainfall of the area is 1264 mm.

Planting materials

Maize variety (BH-661) which is relatively suitable for the intercropping system due to its semi-erect morphology and stay green after maturity and perennial multi-purpose pigeon pea locally adapted to the area were used for the study.

Experimental design and procedure

Twenty one treatments consisted of factorial combinations of four branch removals (pruning) but leaving 0, 2, 4 and 6 upper branches of pigeon pea and five nitrogen levels (18, 41, 64, 87 and 110 kg N ha^{-1}) as well as sole maize with recommended NP were used in a randomized complete block design with three replications. The land was prepared using tractor implement during the initial year (2013) whereas crop residue incorporation and minimum tillage using local digging hoe was used during the second (2014) and third (2015) years of the experiment. Maize was planted at a spacing of 75 cm x 30 cm on a plot area of 19.125m^2 (3.75m x 5.1m). Pigeon pea was also planted between rows of maize at 50cm spacing between plants and branches were removed 8 weeks after planting. During 2014 and 2015 cropping seasons, branches were removed right at planting of maize according to the treatment set up. The removed branches were weighed (biomass weight in this context), chopped and incorporated to the soil of respective plots. Data such as grain and biomass yields for both crops were collected from three center rows.

The composite soil sample was collected from each experimental plot at depth of 0-20 cm before planting (at establishment) and after harvest of each cropping season. Soil samples were weighed and oven dried at 105^0. Samples were analyzed for moisture content and bulk density determinations.

Data collection and management

Grain yield was corrected to 12.5% and 10% moisture content standards for maize and pigeon pea, respectively. Above ground biomass of maize and sample biomass of pigeon pea (pruned branches with leaves) were sun-dried until constant weight was maintained.

Data analysis

Data were analyzed using SAS version 9.1 (SAS, 2008) computer software and were subjected to ANOVA to determine significant differences among factors and their interactions. Means were separated using LSD test (Steel and Torrie, 1981).

Results and Discussion

Biomass and grain yields of maize

Mean maize grain yield obtained from maize/pigeon pea intercropping regardless of pruning options resulted in 6% yield advantage over maize grown sole during the initial establishment of pigeon pea, 2013 main cropping season. Combined maize grain yield, advantage of 1.25% was recorded from maize pigeon pea intercropping compared to the maize monoculture (Table 1).

The main effect due to branch removal of pigeon pea was significant for maize biomass and grain yields. Removing pigeon pea branches but leaving 0 and 2 upper ones produced significantly the highest maize grain yields during the three cropping seasons (Table 1). Indeed, mean maize grain yields of 8940 kg ha^{-1} and 8884 kg ha^{-1} were recorded for branch removals leaving 0 and 2 upper ones, respectively against 8471 kg ha^{-1} obtained by maize grown sole with recommended fertilizer of 110 46 kg ha^{-1} NP_2O_5 (Table 1). Higher maize grain yield in maize/pigeon pea intercropping might have attributed by less competition, addition of organic matter to the soil and improvement of soil moisture. Removal of lower branches but leaving 6 upper ones produced significantly lowest maize grain yield throughout the cropping seasons (Table 1) which presumably due to high shading effect and competition for resources. Likewise Daniel and Ong (1990) confirmed perennial pigeon pea intercropped with sorghum has improved yield of component crop when lower branches were removed. Unaffected grain yield of component crop was also reported by ICRISAT (1987) when plant population of pigeon pea was reduced below 28000 and lower branches were removed.

The main effect of nitrogen level was affected maize biomass and grain yield during the three cropping seasons (Table 1). Application of 110 kg N ha^{-1} and 87 kg N ha^{-1} produced significantly higher maize grain yields during the three cropping seasons (Table 1). Application of 18 kg ha^{-1} produced significantly lower maize grain yield throughout the three cropping seasons, but not significantly different from application of 41 kg N ha^{-1} during 2013 and 2015 cropping seasons.

Biomass and grain yields of pigeon pea

Biomass weight of pigeon pea increased as the rate of pigeon pea branch removal increased throughout the cropping seasons and showed increasing trend for subsequent cropping seasons (Table 2). Pruning of all branches but leaving the growing meristem produced significantly higher biomass weight of 8299 , 8546 and 9255 kg ha^{-1} but not significantly different from removing all branches but leaving 2 upper ones during 2013, 2014 and 2015, respectively (Table 2). Mean biomass weight for removal of all lower branches leaving the upper 6 and 4 were significantly the lowest during the three cropping seasons.

Unlike the biomass weight, seed yield increased as the rate of branch removal decreased throughout the cropping seasons. The main effect of branch removal affected seed yield of pigeon pea throughout the cropping seasons. Certainly, significantly higher seed yields of 1234 , 1339 and 1441 kg ha^{-1} during 2013, 2014 and 2015, respectively were obtained from branch removal but leaving 6 upper ones. All branches removal leaving only the upper meristem produced significantly the lowest seed yields, but as high as 807 kg ha^{-1} during 2015 cropping, considerably additional output obtained from rejuvenated branches during off-seasons (Table 2). Fast re-growth habit of branches after pruning and the time interval from pruning to the crop phenology favored annual seed harvest from perennial pigeon pea.

Table 1. Maize biomass and grain yield as affected by the main effects of pigeon pea branch removal and N level in maize/pigeon pea intercropping at Bako

Factor	Biomass weight (kg ha^{-1})			Grain yield (kg ha^{-1})		
Pigeon pea branch removal & leaving upper	2013	2014	2015	2013	2014	2015
0	24677^{a}	22501^{a}	19547	9987^{a}	8602^{a}	8232^{a}
2	23822^{ab}	21347^{ab}	19616	9822^{a}	8569^{a}	8260^{a}
4	23189^{ab}	20054^{bc}	19891	9523^{ab}	7933^{b}	7897^{ab}
6	22646^{b}	19376^{c}	20031	9011^{b}	7658^{b}	7429^{b}
SE ±	637	210	547	456	109	221
LSD (5%)	1819	1303	NS	599	312	632
Sole maize	22411	18767	21363	9040	8193	8179
N level (kg ha^{-1})						
18	21749^{b}	18783^{b}	17017^{c}	8426^{b}	7015^{c}	6819^{c}
41	24124^{a}	20959^{a}	17953^{c}	9017^{b}	8243^{b}	7158^{c}
64	23654^{ab}	20827^{a}	20041^{b}	10071^{a}	8145^{b}	8132^{b}
87	24366^{a}	21623^{a}	21340^{ab}	10205^{a}	8730^{a}	8671^{ab}
110	2406^{a}	21907^{a}	22505^{a}	10209^{a}	8818^{a}	8995^{a}
SE ±	712	234	612	510	122	247
LSD (5%)	2034	1457	1750	669	349	707
CV (%)	10.45	8.49	10.78	8.47	5.17	10.72

Table 2. Biomass and seed yield of pigeon pea as affected by the main effect of pigeon pea branch removal in maize/pigeon pea intercropping at Bako

Factor	Branch weight kg ha^{-1}			Seed yield kg ha^{-1}		
Pigeon pea branch removal leaving upper	2013	2014	2015	2013	2014	2015
0	8299^{a}	8546^{a}	9225^{a}	721^{d}	747^{c}	807^{c}
2	7016^{ab}	7238^{ab}	7813^{ab}	836^{c}	1001^{b}	1079^{b}
4	6937^{b}	7197^{b}	7642^{b}	931^{b}	951^{b}	1010^{b}
6	5763^{b}	5910^{b}	6360^{b}	1234^{a}	1339^{a}	1441^{a}
SE ±	471.29	466.57	512.39	31.76	37.16	41.87
LSD (5%)	1346	1334	1465	88	106	120
CV %	12.88	25.02	25.57	26.04	14.25	14.96

Soil moisture

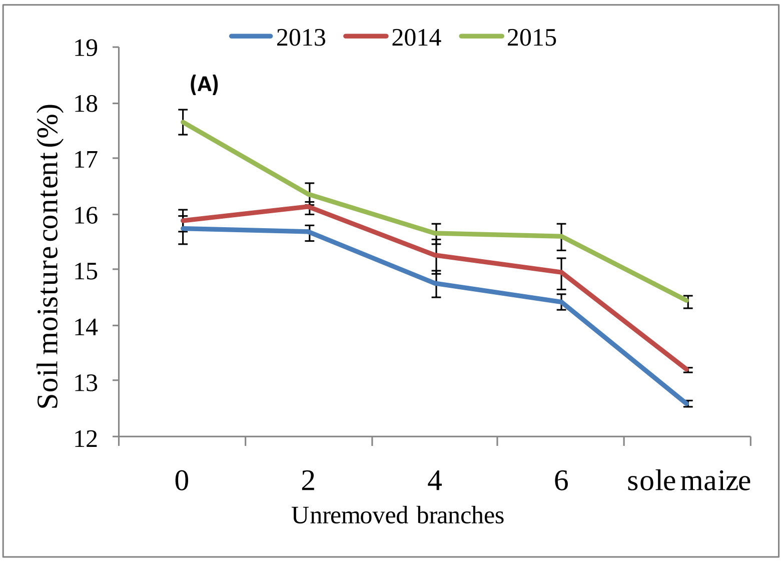
Soil moisture ranged between 12 .5 and 17.8 % being the lowest for maize monocropping and the highest for maize/pigeon pea intercropping while pruniing all lower branches but leaving 2 and 0 upper branches (Fig 1A). Despite of pigeon pea biomass and maize crop residue retention, both the interccropped and sole maize monoculture plots showed increasing trend (Fig. 1A) throughout the three cropping seasons. Indeed, mazie/pigeon pea attainred suitable moisture content for maize growth with respect to the soil type of the Bako area. Similarly, Karuku *et al.* (2014) reported that incorporation of vetch crop residue influenced water content, water use efficiency and increased tomato yield.

Soil bulk density

Bulk density remained above 1.2 for sole maize continous cropinng plots whereby maize/pigeon pea inercropping showed remarkable improvement, maintained below 1.15 for prunining all lower branches but leaving the upper 2 and and the growing meristem (Fig. 1B). The wider range between plots of maize/pigeon pea intercrop and maize sole could be due to large and easily degradable deposit of prunned and incorporated pigeon pea branches resulted from high organic matter build up. Similarly, Shaver (2010) justified crop residue is lighter than mineral matter, promoted more aggregation and increased root activity that favored aggregation as a result reduced bulk density.

Effective Rainfal Use Efficiency (ERUE)

The rainfall received during 2013, 2014 and 2015 cropping seasons was 1431, 1067 and 944 mm, respectively (Fig. 2B). With similar decreasing trend, effective rainfall during the crop growing season was 1227, 830 and 779 mm during 2013, 2014 and 2015, respectively (Fig.2B). Maize ERUE progressively increased from 2013 to 2015 cropping season for all pigeon pea branch removals and for sole maize (crop residue maintained in this case). During 2013 and 2014 cropping seasons, the highest ERUE of 8 and 10 kg ha^{-1} mm^{-1}, respectively were recorded by maize intercropped with pigeon pea removed all lower branches while leaving 2 and 0 upper branches. During 2015, maize intercropped with pigeon pea with respect to all branch management and sole maize produced grain over 10 kg ha^{-1} mm^{-1} (Fig. 2A) which could be attributed due to both pigeon pea branch and maize crop residue maintenance on each experimental plot.



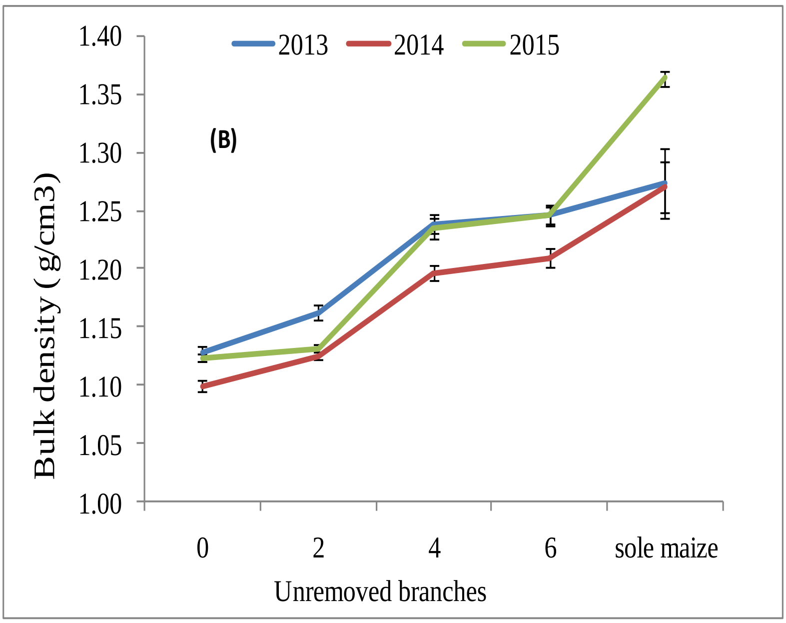
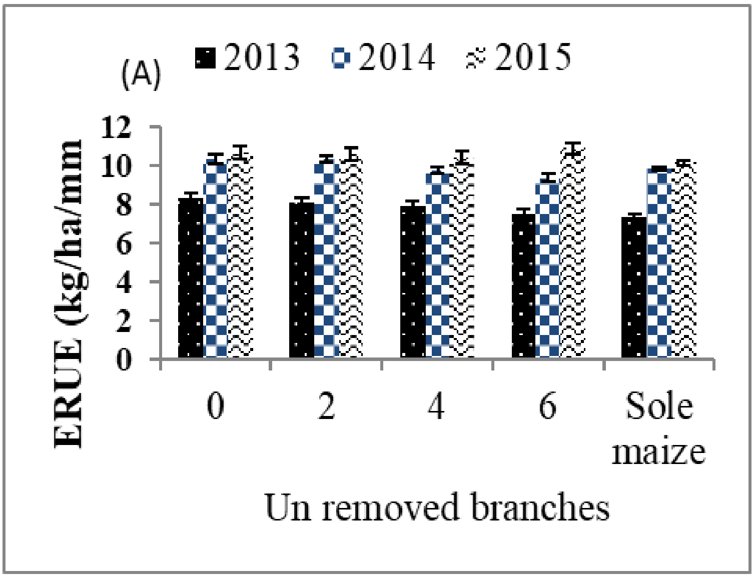


Figure 1: (A) soil moisture and 1(B) bulk density as affected by branch removal of pigeon pea in maize/pigeon pea intercropping at Bako during 2013, 2014 and 2015 cropping seasons



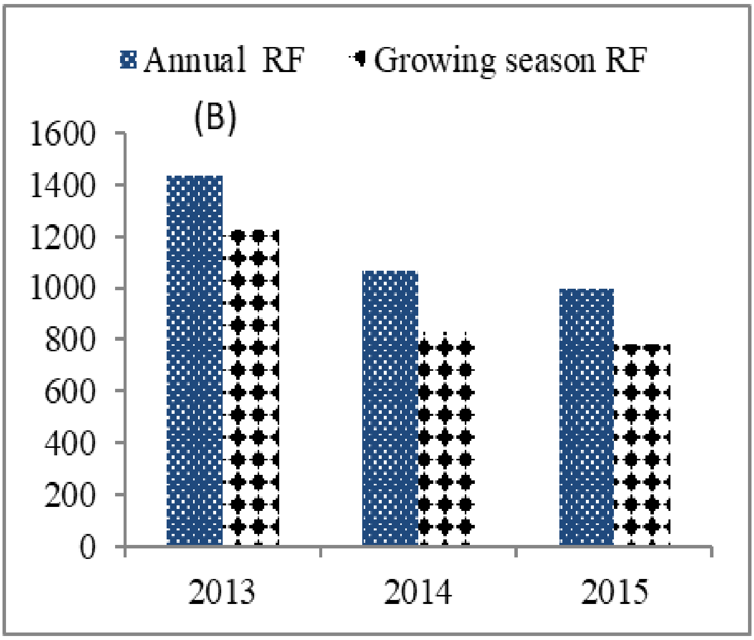


Figure 2: (A) ERUE as affected by branch removal of pigeon pea in maize/pigeon pea intercropping and (2B) Annual rainfall and growing season rainfall at Bako during 2013, 2014 and 2015 cropping seasons

Conclusion

In maize belt areas of western Ethiopia, larger number of hybrid varieties with high yielding potentials is released by research. Obviously, the potential of the crop and land productivity could decrease due to continuous cultivation of the same crop. It is also very difficult to put single technological solutions for multiple productivity threats of the area because important plant nutrients removed with crop residues cannot be replaced from inorganic fertilizer alone. Pigeon pea is an important crop with great potential to reverse the soil fertility decline and improves the yield potential of component crop. The large biomass obtained from pigeon pea improved soil moisture and soil bulk density resulted from increased organic matter whereby competition for light was managed by branch removal and competition for moisture was compensated by the high rain fall distribution in the area and high organic matter restoration from incorporation of pigeon pea biomass to the soil. Seed obtained from pigeon pea is a good source of supplementary digestible protein and starch source for human diet and identified as chicken feed. Grain and biomass yield of maize and maize ERUE was increased at less annual rainfall and less growing season rainfall whereby the maintained biomass improved moisture availability following cessation of rainfall. Maize variety, BH 661 has stay green stem with elongated maturity period in maize/pigeon/pea intercropping so that the integrated biomass prevented the soil from fast drying. Thus, incorporation of perennial pigeon pea to the maize dominated cropping system requires due attention by research and extension system.

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References

Abebe Yadessa and Diriba Bekere. 2002. Effect of biomass transfer of Cajanus cajan with or without inorganic fertilizer on BH 660 hybrid maize variety at Bako, Ethiopia, the 6th conference of Ethiopian society of soil sciences. Addis Ababa, Ethiopia.

Asif, I., H. Shahadat and N. Islam. 2014. Soil organic carbon dynamics for different land uses and soil management practices in Mymensingh. pp. 16-18. In: ICEAB. Proceedings of 5th International Conference on Environmental Aspects of Bangladesh.

CIMMYT. 2010. Socioeconomic profile of maize-legume based farming system in Ethiopia: Characterization of livelihood strategies, production condition and markets. Base line survey for the project "sustainable intensification of maize-legume farming system for food security in

Eastern and Southern Africa" (SIMLESA).

Dagne Wegari, Abaya Temesgen, Solomon Admasu, Solomon Jemal, Alemu Tirfessa, Leggesse Hideto, Fekadu Getenet Gezehagn Bogale, Temesgen Chibsa and Mulugeta Mekuria. 2012. Towards sustainable intensification of maize-legume cropping systems in Ethiopia. pp.120-125. In: Mosisa Worku, M.S. Twumasi-Afriye, Legesse Wolde, Birhanu Tadesse, Gzehagne Bogale, Girma Demissie, Dagne Wegari and B.M. Parasanna (eds.). Meeting the challenges of global climate change and food security through the innovative maize research. Proceedings of the third national maize workshop of Ethiopia, Addis Ababa, Ethiopia.

Daniel, J.N. and C.K. Ong. 1990. Prennial pigeon pea; a multi-purpose species for agroforestry systems. *Agroforestry systems. 10:113-129.*

Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidt, J.S. Gerber, M. Johnnston, N.D. Muller, C. O'Connell, D.K. Ray, P.C. West, C. Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Mofreda, S. Polasky, J. Rockstrom, J.Sheehan, S. Siebert, D. Tilman and D.P.M. Zaks. 2011. Solutions for a cultivated plant. *Nature (478) 7369: 337-342.*

Giller, K., E. Rowe, N. Ridder and H. Keulen. 2006. Resource use dynamics and interaction in the tropics: scaling up in space and time. *Agric. Syst. 88: 8-27.*

Hector, V. and J. Smith. 2007. Green manure crops: pigeon pea: sustainable agriculture green manure crops. Cooperative extension services. College of tropical and human resources, University of Hawaii.

ICRISAT (International Crop Research Institute for the Semi-Arid Tropics). 1987. Annual report, 1986. Patancheru, AP502324., India.

Karuku, G.N., C.K.K. Gachene, N. Karanja, W. Cornelis and H. Verplacke. 2014. Effect of different cover crop residue management practices on soil moisture content under a tomato crop. *Tropical and subtropical agro ecosystem. 17: 509-523.*

SAS. 2002 . Statistical Analysis System (SAS), user guide, statistics SAS Inc. Cary. Northern Carolina, USA.

Shaver, T., 2010. Crop residue and soil physical properties. 22-27pp. In: Proceedings of the 22nd annual central plains irrigation conference, February 24-25, 2010, Kansas.

Snapp, S., and S.N. Silim. 2002. farmer preference and legume intensification for low nutrient environments pp. 289-300. In: Adu-Gyamfi, J.J. (ed). Food security in nutrient-stressed environments: Exploiting plants' genetic capabilities.

Snapp, S., M. Blakie, R. Glibert, K. Bezener . and P. Kanyama. 2010. Biodiversity can support a greener revolution in Africa. *Natl. Acad. Sci. 107 (48): 20840-20845.*

Zerihun Abebe, Shiferaw Tadesse and Meseret Tola. 2016. Multiple advantages of pigeon pea (*Cajanus cajan*) in maize based cropping systems: Used as live stake for climbing bean with phosphorus rates, maize productivity enhancement in mono cropping areas. *J. Natural Sci. Res. 6(19): 58-69.*