Multiple Advantages of Pigeon Pea (Cajanas Cajan) in Maize Based Cropping Systems: Used as Live Stake for Climbing Bean with Phosphorus Rates and Maize Productivity Enhancement in Mono Cropping Areas

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Abstract
Continuous maize based monoculture is one of the major bottlenecks limiting land and crop productivity in western Ethiopia. Pigeon pea plays vital role in rehabilitating degraded land and depleted soils due to its high N-fixation capacity, high biomass production and high litter fall. It can also support climbing bean as live stake. Two sets of the experiment were conducted for five consecutive years at Bako Agricultural Research Center. In 2009 and 2010 cropping seasons, pigeon pea was established and two crops (tef and finger millet) which were considered as one factor were under sown as tangua systems until the pigeon pea reaches its maximum growth. In 2010 and 2011, climbing bean was planted in established pigeon pea under different pruning options (25%,50% and 75% branch remaining) and with P_2O_5 rates (0,15,30 and 46 kg/ha). Thus treatments were arranged in factorial combinations and replicated three times. In 2011 and 2012, maize was planted on the permanent plots that two crops sown during pigeon pea establishment and received pigeon pea biomass under different pruning options and with N application rates (0, 36, 72 and 110 kg/ha) and designed in RCBD factorial arrangement. The result revealed that better biomass and grain yield of finger millet under sown during the establishment of pigeon pea was obtained compared to tef. Significant yield increase of climbing bean was recorded when percentage of pigeon pea branch removal was increased. Application of phosphorus increased grain yield of climbing bean, but there was no significant difference on yield of pigeon pea. Seasonal variability highly affected maize yield performance and the yield was highly reduced during 2012 compared to 2011 due to the lowest annual rainfall amount received in this season against the last ten years. There was strong and positive correlation of maize yield and annual rainfall of cropping season. Maize yield was not significantly different due to the residual effects of pigeon pea biomass retained under different pruning levels. But, highly significant yield increase was observed due to residual effects of retained biomass as compared to farmers' practices and even under maize-climbing bean intercropping. Application of N to maize planted on previous plots that received pigeon pea biomass showed no significant variations though the better yield was recorded when 33 kg/ha N and 72 kg/ha N were applied in 2012 and 2011 cropping seasons, respectively. However, significant yield increases were obtained when the crop was planted on previous plots that were retained by pigeon pea biomass, regardless of N application rates, compared to the sole maize monoculture and in intercropping system. The result also clarifies the performance of maize without N application gave similar grain yield compared to current farmers' practices. Generally, significant yield increment by 6-17% and 5-30% over farmers' practices were recorded in 2011 and 2012, respectively. In short rainy season, maize yield planted on previous plots retained by pigeon pea biomass or as litter fall and with no N performed significantly better than farmers' practices. Retention of pigeon pea biomass or released as litter fall on the following year for maize production can also significantly reduce 66-100% of the total recommended N while significantly increase maize yield. In 2013, the maize was planted on the permanent plots that had pigeon biomass or litter fall and with no chemical fertilizers revealed more than 100% and 75% yield increments as compared to yield of maize under intercrops and farmers' practices. Indeed, pigeon pea can be used as live stake for climbing bean production or pigeon pea-climbing bean intercropping at appropriate pruning level (up to 50% to 75% branch removals). Moreover, the buildup of soil fertility through establishing pigeon pea and its biomass retention evidently boost the productivity of the soil and even 100% reduction of chemical N fertilizer cost. Hence farmers are advised not to apply any N fertilizer sources in the following years since its left over effects significantly enhance maize yield. However, further investigation is needed to specify the frequency of organic matter buildup using this pigeon pea plant and its impact on availability of naturally fixed nutrients, likes phosphorus.
Keywords: Pigeon pea, Climbing bean, Pruning levels, Nitrogen, Phosphorus

Introductions
Sustainable food production is the most critical challenge of today's agriculture for an ever-increasing human population (FAO, 1999). Sustainable agriculture is successful management of resources to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources. However, area of cultivable land per unit household is dwindling from time to time due to population pressures.

This leads to intensive crop production per unit area of land. In the past decades, cultivating more land has mainly increased agricultural production, but there is very limited scope for this since uncultivated land is rapidly diminishing (Beets, 1982).

Declining soil fertility is fundamental impediment to agricultural growth and a major reason for slow growth in food production in sub-Saharan Africa (Smaling *et al.*, 1997). Low soil fertility due to monoculture cereal production systems is recognized as one of the major causes for declining per capita food production (Sanchez, 1995). Therefore, soil fertility replenishment is increasingly viewed as one of the critical to the process of poverty alleviation. This is generally true for Ethiopian agro ecologies, particularly for a dominant maize based mono cropping system of western Oromia, which is one of the major problems leading to decline in soil fertility from time to time and resulting bottleneck for the smallholder maize producer of the region.

Sustainable crop production, therefore, requires a careful management of all nutrients sources available in a farm, particularly in maize based cropping systems. These include inorganic fertilizers, organic manures, waste materials suitable for recycling nutrients, soil reserves, integration of legume crops in maize based mono cropping areas to add N- fixed through biological nitrogen fixation or biomass retentions (Wakene et al., 2007). Integrated plant nutrient management increase and sustain soil fertility and provide a sound basis for flexible food production systems that can grow a wide range of major crops to meet livelihood needs (FAO, 1999). All most all farmers in central western Oromia produce maize as continuous mono cropping or some of them as an intercrop with haricot bean using the recommended 110 N kg/ ha and 46 kg/ha fertilizer for maize (Tadesse and Tolessa, 1998). However, the price of inorganic fertilizer is getting beyond the purchasing power of smallholder farmers because of high production cost and uncertain accessibility in addition to non responsiveness of some soils that leads the farmers to non benefits. Therefore, inclusion of leguminous crops, like pigeon pea in cropping systems has multi advantages in improving and sustaining agricultural productivity.

Perennial pigeon pea may have greater capacity to replenish soil fertility than annual grain legumes by their ability to exploit the residual water and subsoil nutrients that crops cannot utilize, withstand drought, and hence produce higher biomass. Their year-round growth may lead to higher biological N fixation (Giller et al., 1997). Pigeon pea has not only a valuable fertilizer value and also provides a valuable dry season animal feed and seeds for human consumption (Abebe and Diriba,2002). Other advantages of pigeon pea include an absence of recurring establishment costs, opportunity to grow crops simultaneously without sacrificing land and improved soil physical conditions and higher water infiltration because of their root activity (Rao et al., 1998). Pigeon pea offers the benefits of improving long-term soil quality and fertility when used as green manure, cover crop (Bodner , 2007), or alley crop (Mapa and Gunasena, 1995). Maize yields have been increased by 32.1% in West Africa by using pigeon pea as a cover crop (Sogbedji , 2006) since it can contribute about 40 kg N ha^{-1} through N fixation, leaf litter fall and roots (Rao and Willey, 1981). Pigeonpea is also known for its ability to access insoluble phosphates in soils low in P, increasing the availability of soluble P for the following cash crops in the rotation. Research in India showed that the roots of pigeon peas release piscidic acid, which reacts with iron-bound phosphate in the soil to release P (Hector V. and J.smith.2007).

Pigeon pea has been reported to be used as rotation farming and intercropping practices (Sakala et.al. 2000). Other than transferring fixed N to the inter-planted crop, pigeon pea has the ability to bring minerals from deeper soil horizons to the surface also improving soil air circulation (Damaris, 2007). Perennial type of pigeon pea can be intercropped with maize, sorghum, cow pea and haricot bean (Egbe and Adeyemo, 2006). However, most tree legumes could be highly competitive with crops for growth resources if they are not managed properly (Rao et al., 1998). The competition from perennial legumes can be minimized by pruning them low and/or frequently, or by selecting species that produce coppice growth slowly (Duguma et al., 1988).

Climbing types of haricot beans are considered to have the following advantages: high grain yields of up to 5 t ha^{-1}, diverse utilization as human and animal feed, biological nitrogen fixation and large biomass production which is a basis for improvement of soil fertility. Further, the climbing beans play a major role in crop rotation and intercropping systems (Mucheni and Muthamia, 2007). In Ethiopia, climbers are produced by small scale farmers in western and southwestern parts mainly intercropped with maize and grown sole around dried fences.

Despite the better yields of climbing bean varieties, farmers continue to grow poorly performing mixed bush type bean varieties due to lack of seeds and staking materials for climbing beans. Research reports conducted in Kenya revealed that most farmers lack sufficient knowledge on the best staking methods. This implies that although staking has been noted to lead to better yields, lack of appropriate staking materials is a key challenge to the adoption of the technology (Gichangi et.al. 2012). The same authors indicated that the woody sticks used as dry stakes, which are the strongest stakes, are even susceptible to damage by termites. They are also preferred by farmers for other alternative uses such as firewood and constructions. These competing needs therefore, could lead to deforestation and subsequent environmental degradation.

However, uses of multipurpose trees, like pigeon pea with appropriate canopy management help as live stakes to support the climbing bean. Therefore, the competition due to overlapping of growing cycles of pigeon pea used as live stakes and climbing bean in integrated cropping system can be reduced by cutting off the branches of pigeon pea. But information on effect pruning levels of pigeon pea on yield of climbing bean and its residual effects with additions of inorganic fertilizer sources on maize yield are lacking in the area. Generally, the objective of this study was to determine pruning level of pigeon pea biomass on yield of climbing bean and its preceding effects on yield of maize with inorganic nitrogen rates.

Materials and Methods

The experiment was conducted at Bako Agricultural research center during 2010-2013 cropping seasons. Bako sub-site lies at a latitude of 9^0 6' N and longitude of 37^0 9' E and at an altitude of 1650 m above sea level. The location has warm humid climate with annual mean minimum and maximum air temperatures of 13.5 and 29.7 ^{0}C, respectively. The area received average annual rainfall of 1425mm (2011), 886 mm (2012) and 1431mm (2013) with maximum precipitation being received in the months of May to August (Figure 1). Monthly distributions of the rain fall in the cropping seasons were not similar. For instance, in 2012 maize cropping system, monthly rain fall during the growing period, particularly at flowering and silking stage was very low compared to other cropping seasons (Figure 1). The soil of the experimental site was reddish-brown, Nitosol, which is acidic with a pH range of 5.2-5.6. The area is a mixed farming zone and is one of the most important maize (*Zea mays L.*) growing belts in Ethiopia, in which cultivation of tef (Erograstis *tef*), finger millet (*Eleusine coronata*) common bean (phoseolus *vulgaris L.*) and to some extent soybean (Glycine *max L.)* are common. The experimental area was predominantly practiced maize based mono cropping systems in low soil fertility problem that directly influence production and productivity of the cultivated crops.

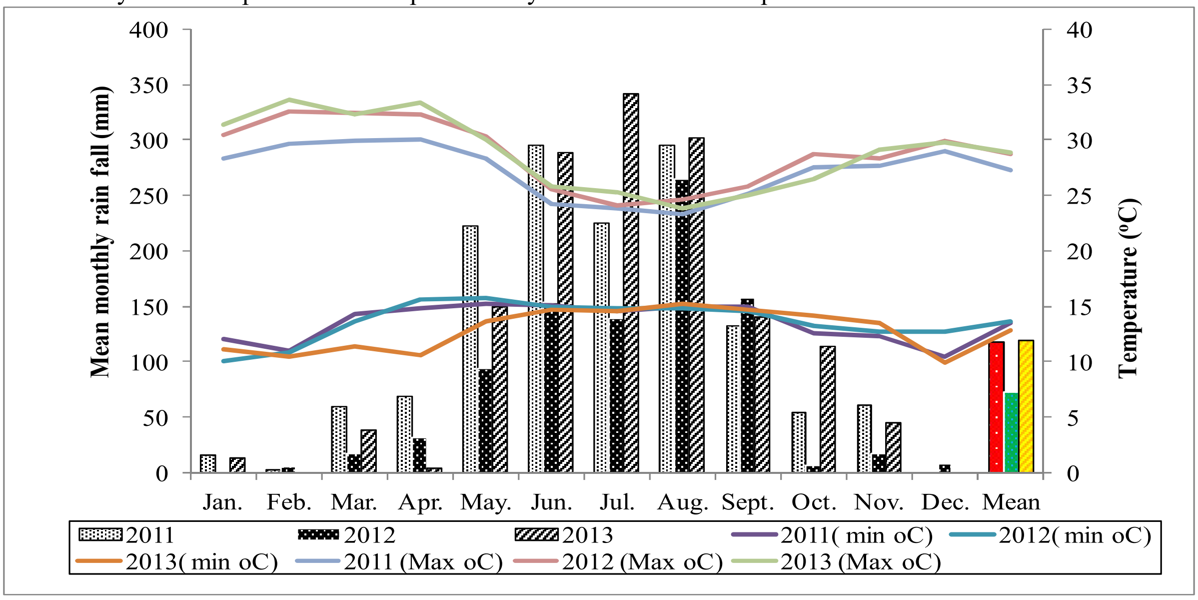


Figure 1: Monthly rainfall, minimum and maximum temperature of Maize growing seasons in Bako Agricultural Research Center (2011-2013)

Two sets of the same experiments were conducted side by side to minimize the experimental periods. During the first year (2009 and 2010) of the experiment, pigeon pea was planted at two selected sites in Bako Agricultural Research center, which was relatively low soil fertility. Pigeon pea was required about nine months to reach full vegetative stage and during the first season of planting it doesn't provide branches that support for climbing bean production. Thus, two crops (Tef and Finger millet) were planted in open spaces between rows of the tree just as tangua systems so that farmers could harvest some crop yield. The spacing of pigeon pea was 1m between rows and 50cm between plants. These crops were simply under sown at recommended time of planting. The same crops were also grown in soles just for comparison purposes.

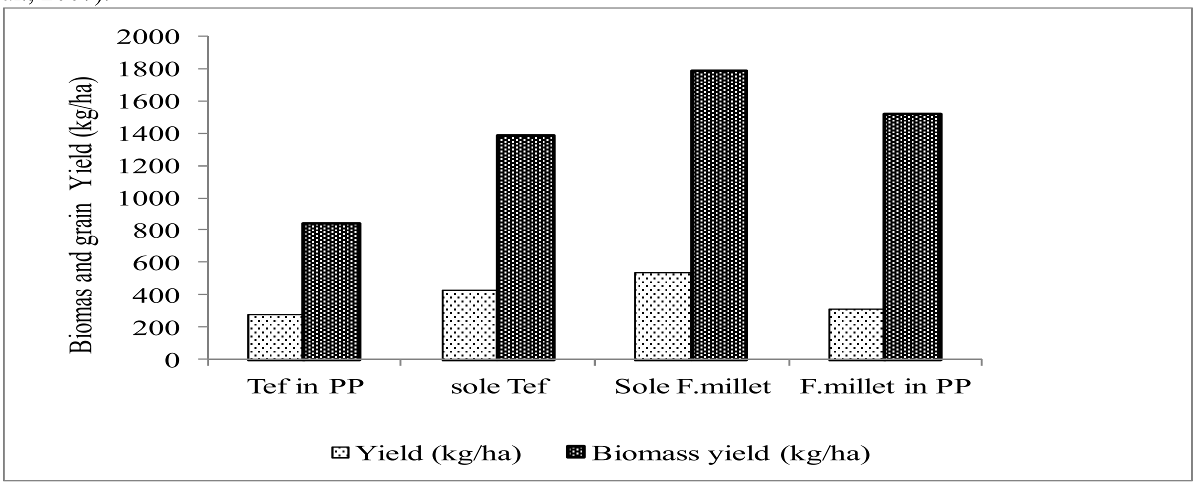
In 2010 and 2011 cropping seasons, climbing bean (Tibe variety) was intercropped in already established pigeon pea in an independent row of 15 cm away from pigeon pea rows. The spacing between rows for climbing bean was 100cm just across pigeon pea rows and 10 cm between plants. Moreover, four levels of fertilizer rates (0, 15, 30 and 46 P_2O_5 kg ha^{-1}) were also applied as another factor. Branches of pigeon pea for both trials in 2010 and 2011 were cut back to 5 cm at different proportion of branch removals, 25% branch remaining (six branches removal), 50% branch remaining (four branch removal) and 75% branch remaining (two branch removals) were also another factors. Thus, the treatments were combined in factorial arrangements of two crops (tef and finger millet) under sown during establishment of pigeon pea as tangua systems, three pruning levels (25%,50% and 75% branch remaining) of pigeon branches and four levels of fertilizer (0, 15, 30 and 46 P_2O_5 kg ha^{-1}) using randomized complete block design in three replications. Sole climbing bean using dry stake and in intercropping systems were also planted just for comparison purpose. The spacing of the bean under dry stake was 40cm x10cm and the spacing in intercropping systems was 75cm x10cm, which was 53% of the total plant population sown under solitary systems. Moreover, plant population of the climbing bean under pigeon pea intercropping was 64% of the total plant population sown under sole cropping using dry stakes. The bean was planted 15cm far away from pigeon pea rows and the spacing between bean plants was 6cm. Pigeon pea branches were removed as per the treatment arrangements and the biomass was measured and incorporated on the respective plots to evaluate its effect on the performance of the next crop.

In 2011 and 2012 years, established pigeon pea plots were uprooted and incorporated to each plot. Maize was planted on permanent plots as per treatment arrangements. Therefore, the treatment arrangements were two crops (tef and finger millet) planted under established pigeon pea and three pruning levels (25%,50% and 75% branch remaining) and retention of the pea biomass on respective plots were factorially combined with N rates (0,36, 72 and 110 N kg/ha) . Therefore, 2x3x4 treatment combinations on permanent plots were arranged in RCBD and replicated three times. Maize was planted with 75cm x 30cm plant populations on the retained plots. BH 540 variety was used as test crop for all cropping seasons. Recommended 46 kg ha^{-1} P_2O_5 was applied for each plot and all other managements were applied uniformly.

In 2013 cropping season, the same variety of maize was planted on each plot without any fertilizer application just to evaluate the residual impact of pigeon pea biomass retained or as litter fall defoliated to the soil. Continuous maize mono cropping (farmers' practices) and intercropping with recommended fertilizer rates were planted on permanent plots in each year of experimental period. All required agronomic data, like pods per plant, biomass and grain yield were collected and subjected to analysis of variance. Gen-stat discovery version three was used to run ANOVA and mean separation was done using LSD. Sigma plot was used for bar graphing.

Result and discussion

Preliminary yield result of tef and finger millet under sown in established pigeon pea revealed that better biomass and economic yield were obtained from finger millet. A minimum grain yield of 0.2 t/ha from tef and 0.3 tons/ha from finger millet under sown in pigeon pea could be harvested. But, greatly high biomass (1.32 tons/ha) could be harvested from finger millet planted in pigeon than Tef (0.82 tons/has) and the same is true under sole cropping systems. But, competition effect of pigeon pea on the companion crops were significantly reduced both biological and economic yield compared to their respective sole crops (Atuahene et al., 2004). The difference in yield performance either under intercropping or sole cropping of the two crops was due to their difference in genetic performances particularly under low soil fertility problem (Muoneke et al. 2007). This preliminarily result indicated that farmers can harvest some biological yield which is used for feeding livestock and grain yield so that under sowing of some compatible crops during the establishment of the perennial crop (pigeon pea) not only give some economic and biological yield but also cover the soil that considerably reduce soil erosion. In other words, covering of the soil with some important crops prevent or reduce both wind and .soil erosion and thereby reduce soil fertility reduction while increasing or maintaining soil organic carbon (Bodner et al., 2007).

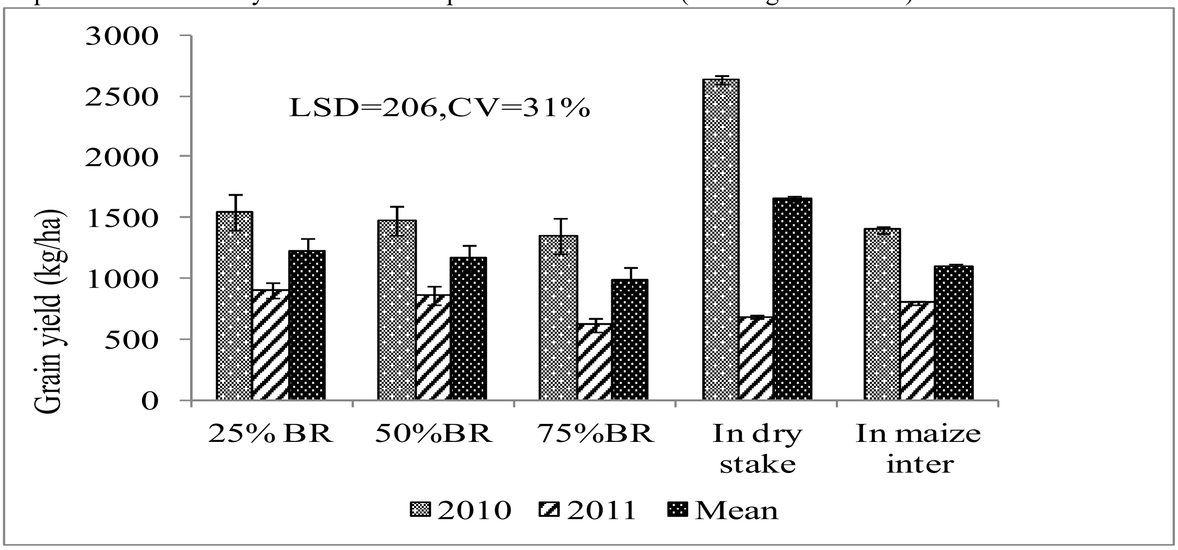


Note: Tef in PP= Tef under soil in pigeon pea; F.millet in PP= finger millet under sown in pigeon pea; F.millet= Finger millet

Figure 2: Preliminarily yield performance of Tef and Finger millet under sown in established pegion pea versus sole cropping systems (2009 and 2010 cropping seasons)

Yieled performce of climbing bean in different cropping system

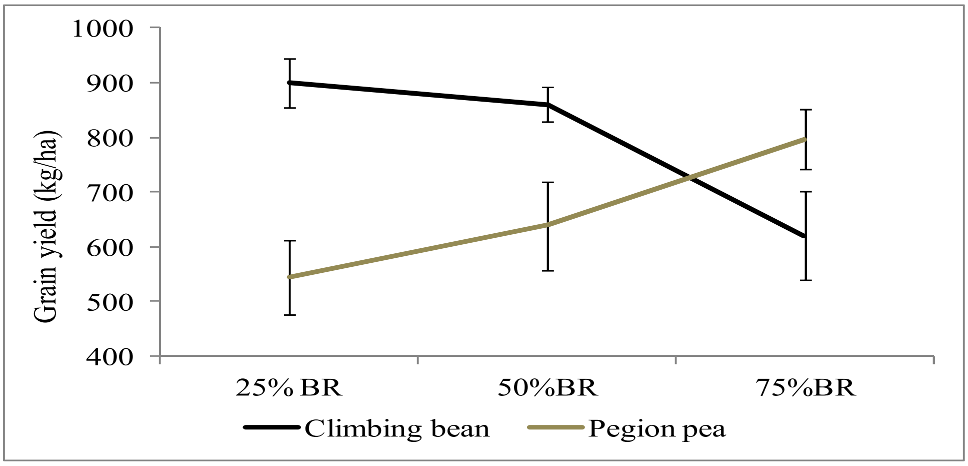
Significant differences were observed across the years (2010-2011) on grain yield of intercropped common bean, which might be enviromental variability and management as well. However, the mean of two years revealed that the highest grain yield was obtained when climbing bean was sown in sole using dry stake. This is because of plant population difference when intercropped in pegion (64%) and in maize (53%) that significatly affected in addition to competition effects. When climbing bean was intercropped uder different canoppy management of pegion pea, significantly higher grain yield was obtained when 25% of total branches (only two branches left at the top) were remained compared to other canoppy management (Figure 3). More than 24% and 18% of significant yield increase were recorded when 25% (two branches) were retained comapred to retention of 75% (six branches) and 50% (four branches) branches . Indeed, bean yield was linearly increased when number of branch removal increased. This result and other findings (Rao et al 1998) indicated that shading effects due to heavy canopy of the livestake significantly reduced yield of the companion crops. On the other hand, intercropping of climbing bean in pegion pea with minimum canoppy significantly increased the grain yield compared to maize-climbing bean intercrops (Egbe and Adeyemo, 2006). Even though, climbing bean planting using dry stake as support significantly out yieled over maize-climbing bean intercropping due to plant population difference, this practice is not advisable to be used by the farmers since it leads to deforestations. However, the highest grain yield (1047 kg ha^{-1}) was obtained when climbing bean was intercropped in maize than in pegion pea though no significant yield difference observed when two and four branches were remained on the plant. When it was planted as sole using dry stake the yield was significantly low, which might be because of some external influences like birds that attack at time of harvesting, which leads to shattering. There fore, intercropping either in maize that are suitable and compatible for the companion crops or pegion pea intercropping with appropriate canopy managemet through branch removal is the best agronomic practices that help to avoid uses of dry stake and hence prevent deforestation (Gichangi et.al. 2012).



25%BR= 25% of total branches remaining (two branches left at top); 50%BR= 50% of branch remaining (four branches were left on pigeon pea plant); 75%BR= 75% of branches remaining (six branches were left on pigeon pea plant); in dry stake= sole climbing bean using dry stake as support; In maize inter= Maize-climbing bean intercropping

Figure-3: Main effect of pruning level of pigeon pea on yield of intercropped climbing bean versus maize-climbing bean intercropping and sole climbing bean using dry stake as support

When yield of both crops were compared, yields of both crops were significantly affected by the effect of branch removal. Thus, there was a significant yield increase for climbing bean and yield decrease of pigeon pea as the function of increasing number of branch removal (Figure-4).



25%BR= 25% of total branches remaining (two branches left at top); 50%BR= 50% of branch remaining (four branches were left on pigeon pea plant); 75%BR= 75% of branches remaining (six branches were left on pigeon pea plant)

Figure-4: The effect of branch removal on yield of climbing bean and pigeon pea intercropping system

The highest yield of pigeon pea was obtained when the upper two branches per plant were removed while the lowest yield was obtained when six branches were removed. Contrary, the maximum yield of common bean was obtained when many branches were removed (Figure 4).

One year (2011) result indicated that grain yield of climbing bean was significantly varied by fertilizer application, but not on yield of pigeon pea though numerical variations were observed (Figure 5). The maximum (1019 kg ha^{-1}) yield was obtained at 46 kg ha^{-1} of P_2O_5 application and 84% yield increase over the control. Application of 30 kg ha^{-1} P_2O_5 also considerably gave more than 58% and 30% yield increase over the control and use of 15 kg ha^{-1} P_2O_5 , respectively. This indicates that 30 kg ha^{-1} P_2O_5 economically optimal to obtain optimum grain yield of haricot bean in pigeon pea intercropping systems. Application of 15 kg ha^{-1} P_2O_5 of the fertilizer didn't significantly increase grain yield over the control.

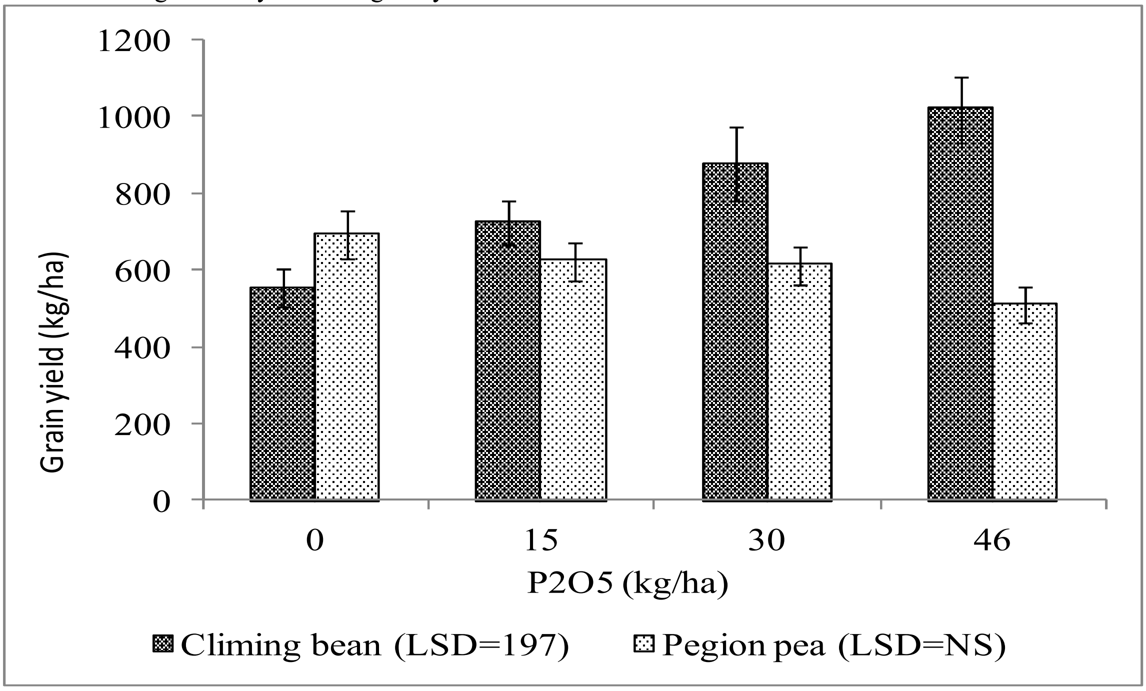


Figure-5: Main effect of fertilizer rates on yield of haricot bean and pigeon pea-climbing bean intercropping systems (2011).

Even though fertilizer application did not significantly vary on yield of pigeon pea, numerically the highest yield was obtained under zero fertilizer rates. This result may indicate that pigeon pea could recycle available soil nutrient since it has long root structure that may mine the soil nutrient from deep soil rather than applied phosphorus on upper soil since it is naturally immobile on the soil solution (Hector and smith. 2007). The same authors also indicated that pigeon pea is able to access insoluble phosphates in soils low in P since it releases piscidic acid, which reacts with iron-bound phosphate in the soil to release P. Another important reason could be its atmospheric nitrogen fixation capacity that may be available for the crop and even for other crops. The research finding was also reported that since the root systems is deep rooted that are able to absorb nutrient from 1-3m deep soil and build up the most required nutrients on the sub-surface layer, and hence it plays for soil fertility enhancement (Grave et al., 2004).

Maize performance due to residual effects of retained pigeon pea biomass and N application

The objective of this experiment was to evaluate yield performance of maize on residual effect of pigeon pea under different levels of canopy managements with some additional nitrogen (N) application. Combined analysis of variance over years revealed that N application rates showed a significant effect on maize yield where as types of crops used during pigeon pea establishment and percentage of branch removal and then retention on the plot and their interaction effects did not show significant differences (Table 1). Highly significant variation in maize yield was also observed due to variation in cropping season.

Table 1: ANOVA table for maize economic yield as affected by different Crops under sown in established pigeon pea, biomass retention of pigeon pea on permanent plots and with some nitrogen application rates across years (2011-2012)

Source of variation	d.f	F Probability value
Year	1	<.001
Crops	1	0.946
Pruning level	2	0.581
N_rate	3	0.033
Crops*Pruning	2	0.056
Crops*N_rate	3	0.092
Pruning*N_rate	6	0.118
Crops*Pruning*N_rate	6	0.058

Seasonal variations significantly influenced yield performances of the crop. Maize yield was significantly reduced by 52% in low rainfall short season (2012) compared to higher rainy seasons (2011). The result also indicated that yield was strongly and positively correlated (R^2=0.99) to the amount of annual rain fall dropped during the growing period of the crop. The amount of the rain in 2012 seasons was dropped down by more 61% compared to 2011 seasons, which significantly influenced the growth and development of the crop (Figure 6). Moreover, monthly distribution of the rain during the growing period, particularly at time of flowering to grain filling stage were different across each growing season. For instance, in 2012 growing period, particularly during October and November the amount of monthly rainfall was 17.1mm and 6.5mm, respectively, which is much less than the average monthly rainfall and the distribution in each day was highly variable, which significantly influence the development of the crops and hence reduce yield performance (Figure 1). Some research reports also refined that maize crops are very sensitive to water deficits during its critical period (flowering to beginning of grain filling) for two reasons: high water requirement, in terms of evapotranspiration, and high physiological sensitivity when determining its main yield components, as number of ears per plant and number of kernels per ear (Hamero et.al.,2007). In contrary, the amount and distribution of the rain during 2011 maize growing seasons was optimum, and thus the performance of crop was significantly better than in low rainfall season.

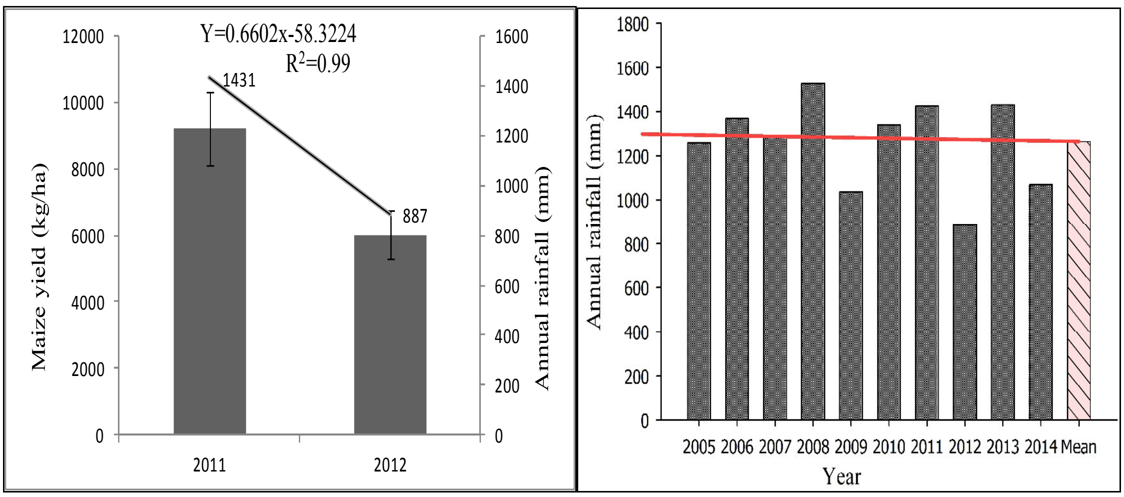


Figure 6: Maize Yield Performance against annual rainfall of cropping seasons (left) and progress of annual rainfall of ten years (right) around Bako Agricultural Research Center

The annual rainfall of ten years in experimental area also confirmed that the amount and distributions of rainfall during 2012 was highly lower by 42% as compared to the ten year mean annual rainfall (Figure 6). Hence, the lowest annual rainfall recorded in the last ten years was in 2012 cropping seasons, and followed by 2009 (1035mm).

In 2011 cropping season, no significant difference of maize yield was recorded under different pigeon pea biomass retentions through branch removal in the previous season (Figure 7). These result indicated that the removal of biomass to transfer to soil is not important since all leaves of pigeon pea naturally defoliated on the ground as litter fall and easily changed to decomposed organic matter with the help of beneficial microbes under optimum soil moisture and temperature. This result is in lined with some findings that high amount of leaf litter naturally released by pigeon pea in one season (up to 3 tons/ha) are considered a potentially viable sources of nutrients for subsequent crops and more than 22% maize yield increase obtained from the field that was previous cultivated with pigeon pea (Mapfumo et al., 2000). Similar result was also revealed in bad cropping seasons (2012) that, no significant variation on maize yield was recorded due to pigeon pea biomass retentions in previous season.

However, continuous growing of maize (farmers' practices) with recommended inorganic fertilizer rates in each cropping season significantly lower in grain yield compared to sole maize planted on residual effect of retained pigeon pea biomass in previous season. On average, more than 50% and 83% yield increment over farmers' practices were recorded during 2011 and 2012 cropping seasons (Figure 7). This indicate that the initial soil fertility status due to continuous mono cropping practices leads to very low nutrients, not only in nitrogen and phosphorus but also others like soil organic carbon that may critically influence soil nutrient availability and absorptions (Wakene 2001).

25%BR= 25% of total branches remaining (two branches left at top); 50%BR= 50% of branch remaining (four branches were left on pigeon pea plant); 75%BR= 75% of branches remaining (six branches were left on pigeon pea plant); FP= Farmers practices (continuous mono cropping of maize with recommended inorganic fertilizer rates); Mz inter= yield of maize when intercropped with climbing bean

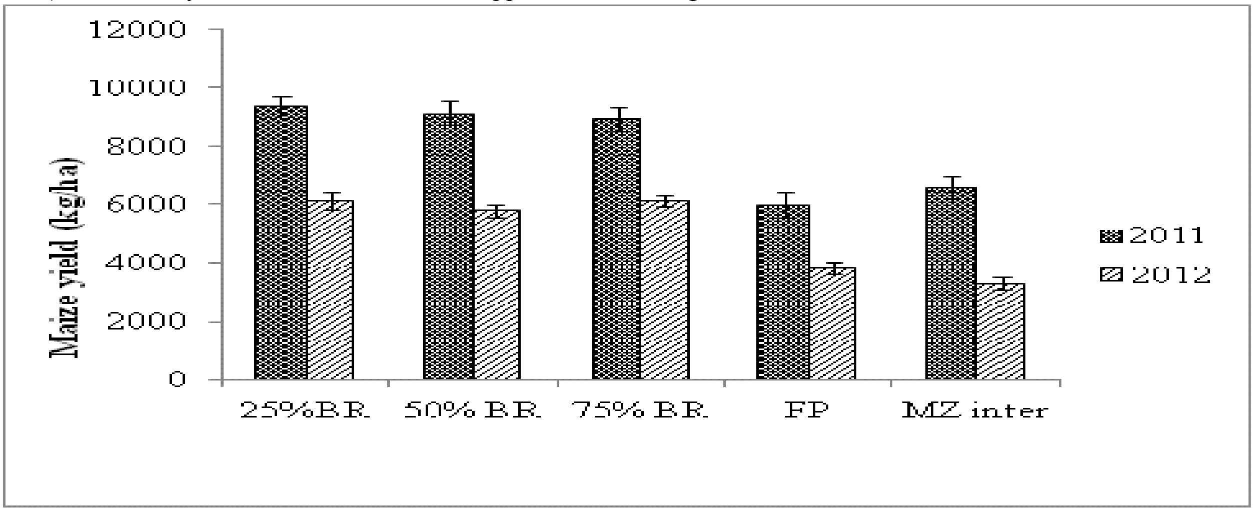


Fig 7: Main effect of pigeon biomass residual effects retained on previous plots versus Maize-climbing bean intercropping and farmers' practices on yield of Maize (2011-2012)

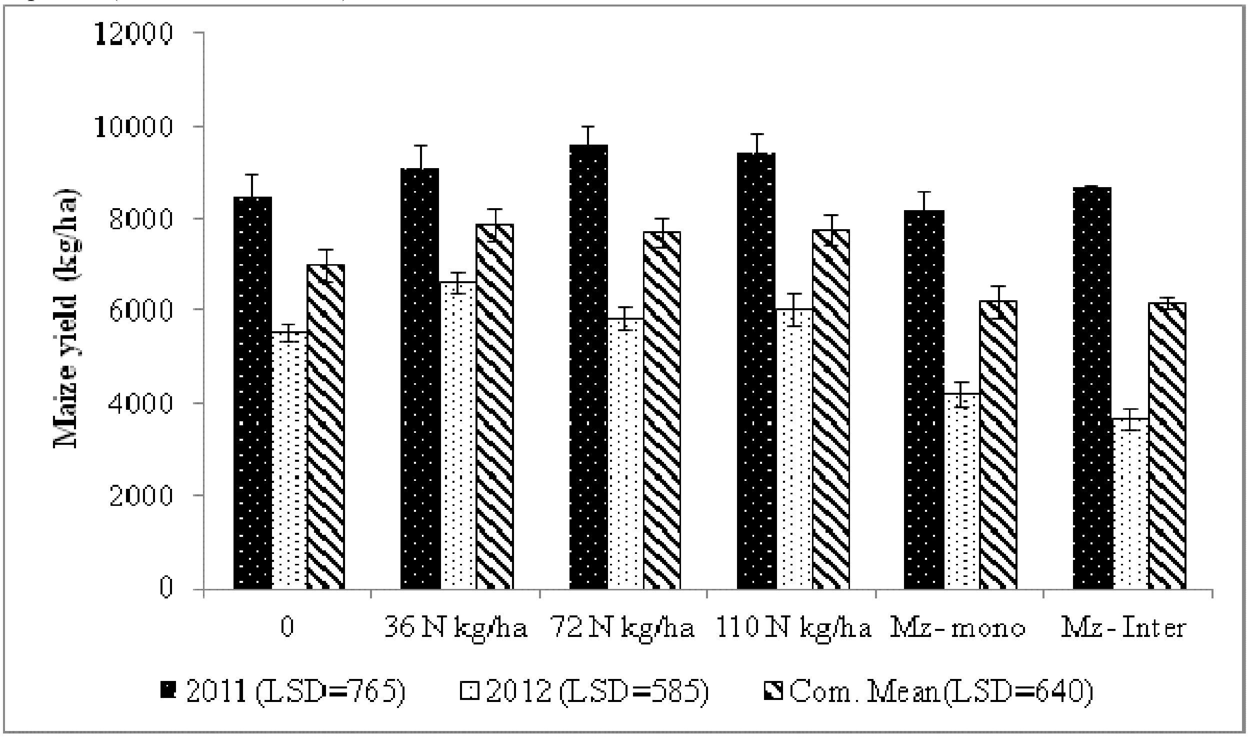
If the soil organic carbon is below the minimum range, the availability and absorption of the nutrient by the crop could be reduced. Obviously, if soil organic matter is enhanced due addition of pigeon pea leaves either through biomass transfer or through natural litter fall, the moisture holding capacity of the soil could be enhanced that majorly help in reducing problems on growing and developing of the crop caused by short rainy seasons (Thierfelder and Wall,2009).

In 2012 cropping seasons, for instance, maize yield performance due to continuous mono cropping with recommended inorganic fertilizer application was significantly lower compared to sole maize planted on retained biomass of pigeon pea plots, which indicate that soil moisture could be much worse in continuous monoculture that might be due to low organic matter, and hence less moisture holding capacity (Khuram and Ghulam. 2011)

Moreover, yield performance of maize in intercropped with climbing bean was significantly better in good rainy seasons (2011) compared to the low rainy seasons (2012) due moisture deficit that may enhance competitions between the associated crops. In high rainy seasons, more than 17% yield increment was recorded when maize was intercropped with climbing bean compared to continuous monoculture. In low rainy season, however, maize yield was reduced by 14% when grown under sole cropping as compared to maize-climbing bean intercropping.

In 2012 cropping seasons, the highest yield was obtained when 33 kg/ha of N was applied to the plots receiving pigeon pea biomass retention though comparable yield was also obtained under no N application (Figure 8). Similar result during 2011 season also indicated that application of N to the maize that was planted on permanent plots and received pigeon pea biomass or litter fall did not show significant variations though higher maize yield could be obtained when 72N kg/ha was applied.

Significant yield increases were recorded due to N application rates ranged from 0- 100N kg/ha when compared with either farmer's practices (maize mono cropping with recommended NP rates) or Maize-climbing bean intercropping (Figure 8). The result clearly showed that performance of maize without external N application, but 100 Kg DAP/ha applied, gave similar grain yield with current farmers' practices (Wakene, 200; Zaman Allah et al., 2007). But, significant yield increment by 6-17% and 5-30% over farmers practices were recorded in 2011 and 2012 cropping seasons, respectively. In short rainy season, the performance of maize planted on previous plots retained by pigeon pea biomass or as litter fall and without N application significantly much better than farmers' practices and even maize-climbing bean intercropping with recommended inorganic fertilizer applications. This might be because of water holding capacity and infiltration of the soil could be improved (Baudron et al., 2011).

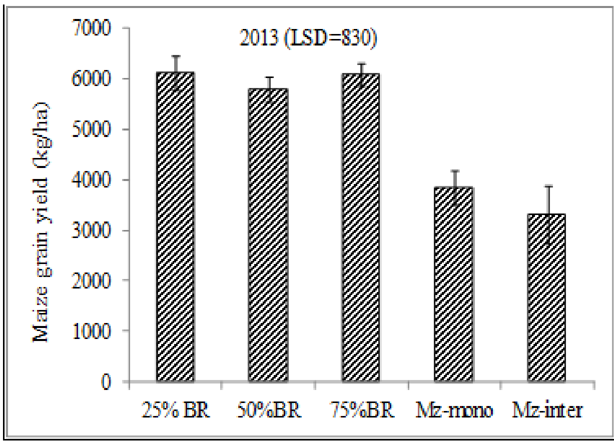


Mz-mono= Continuous mono cropping practices with recommended fertilizer rates; Mz-Inter= Maize-climbing bean intercropping with recommended inorganic fertilizer rates; LSD=least significant difference of means

Figure 8: The effect of N application on maize planted on residual plots receiving pigeon pea biomass versus Maize-climbing bean and farmers practices (2013)

This result indicates that retention of pigeon pea biomass on the following year for maize production significantly reduces 66-100% of the total recommended N while significantly increase maize yield. The utilization efficiencies might have enhanced due to the effect of pigeon pea either through biomass retention or N fixation so that soil physical, biological and chemical properties are improved and hence increase nutrient use efficiencies (Damaris, 2007; Wakene et al., 2007).

In 2013, the maize was planted on the permanent plot without applying any chemical fertilizer whereas farmers' practices and maize-bean intercropping received recommended NP fertilizers. Though the crop was highly affected by tursicum leaf blight, no significant variation among treatment means of maize yield were observed due to the residual effect of pigeon pea biomass obtained under different pruning managements. Whether biomasses of pigeon pea were removed and retained on the soil or not, yield performance was similar. This result indicated that the residual effects of retained biomass or defoliated leaves on the soil in combination with remaining effects of applied chemical fertilizer rates in 2012 cropping seasons could give up to 6.1-6.4 tons/ha without any external fertilizer applications. This indicated that fertility status of the soil gradually enhanced due to gradual releases of the nutrients from organic sources, and the residual availability of applied phosphorus chemical fertilizers also enhanced as some organic compounds that enhance solubility of phosphorus and hence no need to apply continuously in organic matter riches soils (Abebe et.al.,2013).



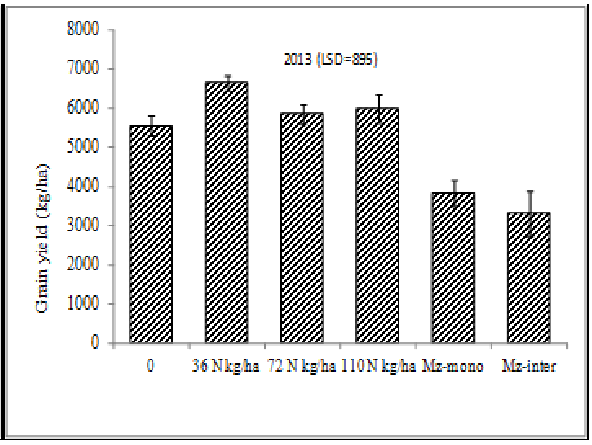


Figure 9: Residual effect of retained pigeon pea biomass (left) and remaining applied N rates (right) versus mono cropping and intercropping (2013 cropping season)

The good interesting thing is that if soil lacks other nutrients and low organic matter rather than NP, utilization efficiency of the applied nutrients were very low which also leads to low yield performances. Continuous mono cropping, farmers' practices' with recommended NP rates showed a significant lower maize yield compared to yield obtained under the residual effects of retained biomass in the soil (Figure 9). On average, more than 42% of significant yield reduction due to continuous mono cropping under chemical NP application rates was recorded as compared to mean yield obtained from residual effects of applied pigeon pea biomass in the previous seasons (Figure 9). Similarly, yield performance under maize-climbing bean with recommended NP rates showed significant 50% lower maize yield though competitions of associated crops might have also another factors contributing to yield reduction of the crop.

The residual effect of applied N on maize yield considerably increased maize yield compared to either maize-climbing bean intercropping or farmers' practices. On average , more than 100% and 75% yield increments were recorded when the maize was planted on the residual effect of applied N in combination of retained biomass compared to yield obtained under maize-climbing bean intercropping and farmers' practices (Figure 9). The reduction of maize yield in intercropping was due to high competition effects of the associated crops in addition to other soil nutrient limiting factors. However, the land productivity of intercropping was more than one, indicating that it is much better to get higher yield from the associated crops per unit area as compared to sole cropping system.

Conclusion and Recommendations

Rehabilitation of degraded soil using pigeon pea establishments under different management systems is one of the best strategies to boost land and crop productivity. This crop has multiple advantages, of course, it play significant role in improving soil fertility through biological nitrogen fixation and organic matter addition within a short period of time. It will also help as live stake for production of climbing bean. Intercropping of climbing bean in pigeon pea with various levels of pruning levels showed a significant yield difference, and 75% branch removal or maintaining two upper branches resulted the highest bean yield. Therefore, pigeon pea/climbing bean intercropping are possible with appropriate canopy management of the perennial crop. Moreover, application of P_2O_5 significantly increased bean yield, and hence addition of chemical fertilizer is important to enhance the productivity of the associated crops, particularly climbing bean.

Seasonal variability significantly influenced maize yield in 2011 and 2012 cropping seasons. The amount and distribution of rainfall is very much important even for the responses of crop to the applied inputs. But, the most important thing is that the residual effects of applied pigeon pea biomass significantly enhanced yield performances even under short rainy seasons compared to intercropping or farmers' practices. This might be increased build up of soil organic matter, enhance soil fertility and moisture holding capacity. Biomass removal and retention to soil did not show significant yield difference, but it is necessarily to manage for climbing bean intercropping. Moreover, significant yield increases were recorded due to N application rates ranged from 0-100N kg/ha when compared with either farmer's practices or Maize/climbing bean intercropping. Among the applied N treatment means, even zero N application on maize that planted on permanent plots received pigeon pea biomass in the previous season gave comparable maize yield as compared to either 36 kg/ha N, 72 kg/ha N or 110N kg/ha application. Moreover, up to 6.1-6.4 tons/ha of maize yield in 2013 could be harvested without any additional fertilizer applications compared to farmers' practices (3.8 tons/ha) and intercropping systems. This result might confirm that nutrient availability and absorption might depend on the initial soil fertility status, particularly soil organic matter that critically influences nutrient availability and absorption to the crop.

It can be concluded that pigeon pea can be used as live stake for climbing bean production or pigeon pea-climbing bean intercropping at appropriate pruning level of canopy management. The buildup of soil fertility through establishing pigeon pea and its biomass retention evidently boost the productivity of the soil and even 100% reduction of chemical N fertilizer cost for maize production, and hence farmers are advised not to apply N fertilizer sources during the year(s) of residual effects significantly enhance optimum maize yield. But, further investigation is needed to specify the frequency of organic matter buildup using this pigeon plant and even its impact on availability of naturally fixed phosphorus.

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