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Suitability of Planting Pattern on Growth and Yield of Maize Intercropped with legumes in smallholder Irrigated Lowveld Condition of Zimbabwe

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ABSTRACT

Intercropping cereal/legumes can improve crop productivity because legumes improve soil fertility. An experiment was carried out at Chiredzi Research Station semi-arid region of Zimbabwe. The objectives were to evaluate the impact of cowpeas/soybeans intercrop on maize yield; finding the most convenient planting pattern maize/cowpeas and maize/soybeans intercrop and assessing the performance of cowpeas/soybeans as supplementary source of nitrogen. The treatments were maize sole crop, legumes sole crop; one row legume; two rows legume; three rows legume; maize/legume same row; sole maize+40kgN/ha.; one row legume+70kgN/ha.; two rows legume+70kgN/ha and three rows legume+70kgN/ha. Results indicated that intercropped maize took significantly longer days to mature in both maize/cowpeas/soybeans intercrop compared to sole crop without topdressing. Maize1000 seed weight in maize/cowpeas intercrop increased significantly. Intercropping without topdressing was effective in terms of Land Equivalent Ratios. Intercropping same row maize/cowpeas increased residual nitrogen significantly. Intercropping maize/soybeans 1:1, 1:2, and 1:3 without topdressing increased residual nitrogen significantly.

INTRODUCTION

Maize (*Zea mays*) remains the third most important crop among cereals after rice and wheat across the globe (Dwivedi et al. 2015). It is widely grown in many developing countries including Zimbabwe. Maize is considered a staple food in Zimbabwe besides its other uses for energy. In Zimbabwe maize yields have declined over years due to an array of reasons which include poor soil fertility, poor fertility management and low rainfall caused by global warming and climatic change. Declining crop yields in the smallholder sector presents the need to develop a more sustainable cropping system. Due to high cost of inorganic fertilizers the majority of smallholder farmers are growing cereals in soils deficient in nitrogen, phosphate and potassium.

Intercropping legumes and cereals can be a principal means of intensifying crop production both spatially and temporally to improve crop yields (Gabatshele et al. 2012). Intercropping is the simultaneous growing of two or more crops in the same field (Takim, 2012) and is a cropping system that has been used for a long-time under crop production systems. Maize has been recognized as a common component crop in most intercropping systems. It seems to lead as a cereal constituent of intercrop and is regularly combined with dissimilar legumes (Maluleke et al. 2005). Legumes are potential source of plant nutrients that compliment and or supplement inorganic fertilizers (Jeranyama et al. 2000). It has advantages that include better use of physical resources such as solar radiation, mineral nutrients and water; high labor productivity per unit time and space and reduction in risk of complete crop failure (Zulu, et al. 1998; Thayamini and Brintha 2010). Reduction in yields of component crop may occur due to intense competition. This situation in which two or more plants share the same growth factors each far below their combined demands in the same environment is known as competition (Thole 2007).

Series of research work has been reported by scientists on cereal-legume intercropping (Waddington et al. 2007; Egbe 2010; Osman et al. 2011; Ijoyah 2012) with intercropping successes compared to monocropping. These studies have shown that legumes when intercropped with maize, can work more or less as a substitute for nitrogen fertilizers (Jeranyama et al. 2000) accounting for more than 20% of global biological nitrogen fixation (Geiler, 2001). The spatial arrangement of crops helps in the effective utilization of land, soil moisture, nutrients and solar radiation (Gurigbal 2010). This is brought about by choosing appropriate crops of varying morph-physiological nature and planning their planting geometry to reduce mutual competition for resources and enhance complementarities to increase overall productivity (Gurigbal 2010). Therefore there is greater potential to integrate legume in the existing maize cropping systems as intercrops in semi-arid regions. Legumes can relocate fixed nitrogen to intercropped cereals through their joint growing period and this nitrogen is an important resource for the cereal (Bhagah et al. 2006). This technology benefits the current maize companion crop, and obviously subsequent crops.

Cowpeas (Vigna angulata) and soybean (Glycine max) are major legumes that are grown and used as food and cash crops in Zimbabwe. Crop production by smallholder farmers of Zimbabwe is gradually going down. One of the main reasons why productivity is flopping is lack of inputs including inorganic fertilizers which are so expensive that most of the small scale farmers cannot afford. Intercropping leguminous crops like cowpeas and soybeans with cereal crops could significantly improve nitrogen availability to cereal crops hence sustain productivity. Soybean is a key component of global food security as a source of protein for human food and animal food, oil for cooking and bio-fuel (Sinclair and De Wit 1976; Undie et al. 2012). Leguminous crops have a mutually beneficial relationship with bacteria such as Rhizobium and Bradrhyzobium that are naturally present in the soil (Dupuy et al. 1994). These bacteria infect the root hairs and cortical cells of legumes inducing formation of root nodules that serve as the site of nitrogen fixation. The legume plant provides the bacteria with carbohydrates and the bacteria reciprocate by supplying the plant with fixed nitrogen compounds (Dupuy et al. 1994). The small piece of land, about 0.1 ha, allocated to individual households is too small for growing reasonable areas of more than one crop as sole crops.

If maize and legumes are intercropped, the maize crop will benefit to a greater extend in terms of nitrogen needs due to abundant nitrogen that will be biologically fixed by the legumes (Giller et al. 1994). In addition to that, legumes act as cover crops and they reduce soil erosion (Scott et al. 1987), smoother weeds (Stute and Posner, 1993) conserve soil moisture (Utomo et al. 1990). Different legumes fixing nitrogen ability differ from each other (Fankow-Linndberg and Dahlin 2013), and therefore performances of the intercropped maize tend to differ significantly. The experiment is aimed at evaluating the impact of intercropped cowpeas and soybeans on maize yield, finding the most convenient planting geometry or pattern when intercropped with cowpeas or soybeans and assessing the performance of cowpeas and soybeans' abilities in supporting the intercropped crop of maize as a supplementary source of nitrogen. However, the experiment is limited because it is beneficial to smallholder farmers only. Commercial farmers usually do not intercrop because intercropping makes harvesting difficulty since commercial farmers use combine harvesters. Use of herbicides is also a challenge because of crops' morphological differences. Harvesting is also a problem since the two crops may reach maturation at different times.

MATERIALS AND METHODS

The experiment was conducted at Chiredzi Research Station (210S' and 310 E) located in the South East Lowveld of Zimbabwe in Natural Region V at an altitude of 429 m.a.s.l. The Natural Regions are a classification of the agricultural potential of the country from Natural Region 1, which represents the high altitude wet areas to Natural Region V, which receives low and erratic rainfall averaging 500 mm per annum. The soils are paragneis which are reddish-brown sandy clays. The area is is generally hot, dry and frost free with mean annual rainfall of 500 mm with a seasonal range of 250-1000 mm. A crop of cassava which was planted without fertilizer was harvested and a composite soil sample was collected from 30 cm depth before trial establishment. The field was ploughed using a disc plough. Disc ploughing was chosen because of its ability to improve water holding capacity and water retention by the soil as well as burying of weeds. After ploughing the field was harrowed with a disc harrow to obtain a fine tilth which is needed for better germination and subsequent growth of a crop (Reddy and Reddi, 1992). After crop harvest soil samples were taken from each treatment and analyzed by Chemistry and soils Research Institute. The legume was seeded in one, two and three rows between maize rows and on the same row with maize. The experiment comprised of ten (10) treatments replicated three times in a randomized complete block design (RCBD) with slope as the blocking factor. Maize variety SC 513, cowpeas variety CBC 2 and soybeans variety Santa were used in the experiment. Compound D 300 kg/ha was applied as basal to all the plots. Ammonium nitrate was applied at the rate of 70 kg/ha to maize in the intercrop. The second sole maize plot received 140 kg/ha N while the other maize sole crop did not receive any top dressing. The second sole maize treatment was created to find the additional benefit obtained by applying the required amount of nitrogen compared to the one without top dressing (wtd).

At harvest all the above ground stover was removed from the field for both cereal and legumes. The maize/legume stumps and roots were incorporated using a disc plough in preparation for the next season. The plant population for maize sole crop was 44 444 (0.9 m x 0.25m) plants per hectare, sole soybean 444444 (0.45 m x 0.05m) plants per hectare and sole cowpea 222222 (0.45 m x 0.10 m) plants per hectare. An increase in the number of legume rows made the maize plant population per hectare to reduce. Intercropping was assessed, relative to that of sole crops wtd, by use of Land Equivalent Ratios (LERs), which is defined as the proportion of land area that is required for sole cropping to produce the same yields as intercropping (Mead and Willey, 1980).The equation was as follows: $LER = Lm + Lc = Ym/Sm + Yc/Sc$ where Lm and Lc are the LERs for maize and cowpea/soybean crops respectively. Ym and Yc are the respective yields of maize and legume in intercropping and Sm and Sc are the respective yields of maize and legume in sole cropping (Mead and Willey, 1980). The LER of sole maize top dressed (td) was calculated against the sole maize wtd. When the Land Equivalent Ratio is greater than one (unity) the intercropping favors the growth and yield of the species, whereas when the Land Equivalent Ratio is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures (Willy 1979).

Treatment

1. Maize sole crop (Basal only) without top dressing (wtd)
2. Legumes sole crop (Basal only)
3. One row legume (1:1) basal without top dressing (wtd)
4. Two rows legume (1:2) basal without top dressing (wtd)
5. Three rows legume (1:3) basal without top dressing (wtd)
6. Maize/legume in the same row basal without top dressing (wtd)
7. Sole maize basal +140kgN/ha. (td)
8. One row legume (1:1) basal + 70kgN/ha (td
9. Two rows legume (1:2) basal + 70kgN/ha (td)
10. Three rows legume (1:3) basal + 70kgN/ha (td)

RESULTS

Days to flowering and maturity

Intercropping did not have any significant effect on the number of days to flowering on maize when intercropped with both cowpeas (p=0.491) and soybeans (p=0.358) table 1. However, the number of days to maturity were significant among cropping patterns maize/cowpeas p=0.004 and maize/soybeans p=0.05. Sole maize (wtp) took significantly p=0.004 (96 days) in a maize/cowpeas intercrop compared to 1:1 (98 days); 1:2 (98.7 days) and 1:3 (99.3 days) wtp. In a maize/soybean intercrop maize took significantly longer days p=0.05 days to maturity compared to maize sole crop wtp. However, when 140 kg/ha N was applied to maize sole crop the number of days did not differ significantly with intercropping but took significantly longer with tp (98.3 days) compared to maize sole crop wtp (94.7 days).

One thousand seed weight

Planting pattern maize/cowpeas had significant effect p=0.023 on 1000 seed weight. There were significantly heavier seed weight differences (table 1) on 1000 seed weight of maize maize/cowpeas 1:2 compared to both sole maize crops tp/wtp. Planting maize/cowpeas in the same rows showed significantly heavier seeds p=0.023 compared to sole maize wtp. Planting pattern maize/soybeans did not have significant effect p=0.461 on 1000seed weight.

Five cob grain weight (g)

Samples collected from maize/cowpeas intercrop showed no significant seed weight differences p=0.732 across seasons. However, 5 cob sample weight from maize/soybeans showed significant p=0.05 differences. Maize/soybeans intercropping 1:2 with nitrogen showed significantly heavier seed p=0.05 weight compared to 1:3 tp/wtp. Intercropping maize/soybeans 1:1 and 1:2 did not show any significant differences tp/wtp on 5 grain weight.

Land Equivalent ratio (LER)

All intercrops gave LER above 1showing additional benefits over sole cropping wtd. The LER is the relative area of land under sole crop which is needed to obtain the yield produced in intercropping (Wiley, 1979). LER increased significantly p=0.002; 0.006 and 0.014 first second and third year respectively when maize/cowpeas were intercropped. Intercropping wtp gave the same LER as intercropping with td. Therefore intercropping wtd was beneficial. Sole maize td gave significantly p= 0.002 the highest LER of 2.14. However in the second and third year maize cowpeas 1:1 intercrop td had significantly the highest LER p= 0.006 (1.80). In the first year maize/soybeans intercrop did not show any significant differences p=0.506. Combined analysis showed that there were significant differences obtained when maize/cowpeas were intercropped. Intercropping maize/cowpeas td did not show significant differences to intercrop wtd. However sole cropping maize td showed significantly higher LER p=0.033 (table 2). No significant differences between sole crop and intercropping wtd. However, when nitrogen was applied maize/cowpea intercropping showed significant differences to sole crop. Intercropping maize/soybeans showed significantly higher LER (1.65) in 1:2 wtd. Intercropping td showed significantly higher LER to sole crop. Intercropping 1:2 and maize/soybeans in one row showed significantly higher yields to sole crop and were the same with 1:1; 1:2; 1:3 when td.

Residual nitrogen

There were significant differences shown in the amount of N left in the soil after harvesting maize/cowpeas 1:1 wtd compared to sole maize wtd (table 3). There were also significant differences in the amount of N left in the soil after harvesting maize/soybeans 1:1; 1:2 and 1:3 wtd. However, there were no significant differences p=0.024 with sole maize td in a maize/cowpea intercrop. Increasing the number of cowpea rows in an intercrop did not give significant increase in residual nitrogen wtd maize. However, when the intercropped maize received applied nitrogen 1:3 had significantly higher residual nitrogen compared to 1:1 td in maize/cowpeas intercrop. More residual nitrogen was recorded in soybeans intercropping compared to maize/cowpeas intercropping. When nitrogen was applied to an intercrop the maize crop became more competitive for light, water and space affecting legumes productivity in terms of nitrogen fixation. The amount of residual nitrogen left in the soil ended up the same with maize was td or wtd.

DISCUSSION

Days to flowering and maturity

Intercropping did not have any significant effect on the number of days to flowering for maize when intercropped with both cowpeas and soybeans. However, the number of days to maturity was significant among cropping patterns maize/cowpeas and maize/soybeans intercropping. Intercropping maize/cowpeas showed significantly longer days to maturity compared with sole cropping wtd. The sole maize crop grew and matured faster because of more efficient utilization of resources such as light, water and nutrients in both maize/cowpeas and soybeans intercropping systems Li et al. (2006) coupled with an efficient use of intercepted Photo-synthetically active radiation (PAR) resulting from differing canopy architecture compared to distinct row systems (Kermah 2017). Sole maize wtd took significantly less days to mature compared to intercropping. In an intercrop legumes acted as ground cover crop during the early season and subsequent growth of legumes in intercrop maintained canopy humidity during the later season and maximized the utilization of light (Postma & Lynch, 2012). However there were no significant differences between sole maize td and wtd under the maize cowpeas intercrop. However, when 140 kg/ha N was applied to maize sole crop the number of days did not differ significantly with intercropping but was the same with sole crop wtd.

0ne thousand seed weight

Planting pattern maize/cowpeas had significant effect on 1000 seed weight. There were significantly heavier seed weight differences $p<0.05$ (table 1) on 1000 seed weight of maize in maize/cowpeas 1:2 compared to both sole maize crop td and wtd. This concurred with the findings of Oljaca et al. (2000) who found out that 1000 seed weight increased in intercrops compared to sole crop. Planting maize/cowpeas in the same rows showed significantly heavier seeds p=0.05 compared to sole maize wtd. This may have been attributed to Planting pattern maize/soybeans did not have significant effect $p>0.05$ on 1000 seed weight.

Five cob weight

Cropping pattern had a positive effect on 5 cob seed weights. Soybeans planted on the same row with maize showed significant seed weight differences compared to 1:3 wtd. Li et al. (2013) and White et al. (2013b) found out that cereals obtained additional nitrogen from that released by legumes into the soil. This might be the reason why the 5 cob weight was more when soybeans were planted in the same row with maize. According to Walley (1996) some nitrogen can be "leaked" or "transferred" into the soil (34-57 kg N/ha) for neighboring non-legume

Table 1: Maize/cowpeas and maize/soybeans intercropping system on days to flowering, maturity, 1000 seed weight and 5 cob grain weight across seasons.

Treatments	Maize Days to flower (Maize/ cowpeas)	Maize Days to flower (Maize/ soybeans)	Maize Days to maturity (Maize/ cowpeas)	Maize Days to maturity (Maize/ soybeans)	Maize 1000 wt (g) (Maize/ cowpeas)	Maize 1000 wt (g) (Maize/ soybeans)	Maize 5 cob grain wt (g) (Maize/ cowpeas)	Maize 5 cob grain wt (g) (Maize/ soybeans)
Sole maize basal dressing	61.7	62	96^{d}	94.7^{b}	289.7^{c}	265.3	657.7	656^{abc}
vSole legume basal dressing	-	-	-	-	-	-	-	-
Maize/legume 1:1 row ratio	63.3	62	98^{abc}	97.3^{a}	320^{abc}	326	476.7	627.7^{abc}
Maize/legume 1:2 row ratio	61.3	63	98.7^{a}	97.7^{a}	365^{a}	276.7	732	577.3^{abc}
Maze/legume 1:3 row ratio	62.7	63	99.3^{ab}	98.3^{a}	332.3^{abc}	284.3	563	397.7^{c}
Maize/legume in one row	61.7	62	97.7^{bcd}	97.3^{a}	345^{ab}	303.7	812.7	705.3^{ab}
Sole maize basal + 140 kg/ha N	61.7	62	96.7^{cd}	98.3^{a}	309^{bc}	367	706	847^{a}
Maize/legume 1:1 row ratio + basal + 70 kg/ha N	62	62	99.3^{ab}	97.0^{ab}	338.7^{abc}	316	774.7	718.3^{ab}
Maize/legume 1:2 row ratio + basal + 70 kg/ha N	62	62	98.3^{abc}	99^{a}	344^{abc}	307.7	669.7	757.3^{a}
Maize/legume 1:3 row ratio + basal + 70 kg/ha N	62	63	99.7^{a}	98^{a}	343.3^{abc}	311	594.3	453.3^{bc}
Mean	61.9	62	98.2	97.5	331.9	306.4	665	638
CV%	1.1	1.1	1.0	1.4	8.4	16.9	34.6	24
LSD	1.218	1.207	1.739	2.376	48.3	89.4	398.8	269.6
SE	0.704	0.697	1.005	1.373	27.9	51.6	230.4	154.9
P-value	0.491	0.358	0.004	0.05	0.023	0.461	0.732	0.05

Table 2: Effect of intercropping on LER .

	Maize cowpeas Year 1	Maize soybeans Year 1	Maize cowpeas Year 2	Maize soybeans Year 2	Maize cowpeas Year 3	Maize soybeans Year 3	Across Years Maize/ cowpeas	Maize/ soybeans
Treat.	LER	LER	LER	LER	LER	LER	LER	LER
Sole maize basal dressing only	1^{c}	1.00	1^{d}	1^{c}	1^{c}	1^{d}	1^{f}	1^{f}
Cow peas sole crop	1^{c}	1.00	1^{d}	1^{c}	1^{c}	1^{d}	1^{f}	1^{f}
Maize/legume 1:1 row ratio	1.19^{bc}	1.25	1.42^{abc}	1.46^{bc}	1.45^{ab}	1.36^{bcd}	1.35^{def}	1.36^{def}
Maize/legume 1:2 row ratio	1.23^{bc}	1.59	1.16^{cd}	1.70^{b}	1.29^{bc}	1.65^{abc}	1.23^{ef}	1.65^{bcd}
Maze/legume 1:3 row ratio	1.01^{c}	1.29	1.63^{ab}	0.99^{c}	1.52^{ab}	1.14^{cd}	1.39^{f}	1.14^{ef}
Maize/legume in one row	1.08^{c}	1.52	1.32^{bcd}	1.71^{b}	1.27^{bc}	1.62^{abc}	1.22^{ef}	1.62^{bcd}
Sole maize basal + 140 kg/ha N	2.14^{a}	1.56	1.32^{bcd}	2.60^{a}	1.32^{bc}	2.08^{a}	1.59^{bcd}	2.08^{a}
Maize/legume 1:1 row ratio + basal + 70 kg/ha N	1.53^{b}	1.77	1.80^{a}	1.72^{b}	1.78^{a}	1.75^{ab}	1.70^{bcd}	1.75^{abc}
Maize/legume 1:2 row ratio + basal + 70 kg/ha N	1.38^{bc}	1.71	1.69^{ab}	1.98^{b}	1.44^{ab}	1.85^{ab}	1.50^{bcde}	1.85^{ab}
Maize/legume 1:3 row ratio + basal + 70 kg/ha N	1.37^{bc}	1.49	1.58^{ab}	1.90^{b}	1.40^{b}	1.70^{abc}	1.45^{cde}	1.70^{bcd}
Mean	**1.29**	**1.42**	**1.39**	**1.6**	**1.35**	**1.51**		**1.43**
CV%	17.8	35.7	17.42	21	16.28	16.7		13.5
LSD	0.4	0.845	0.41	0.56	0.36	0.57		0.320
SE	0.13	0.566	0.14	0.338	0.13	0.25		0.193
P-value	0.002	0.506	0.006	<0.001	0.014	<0.001		0.033

Table 3: Maize/cowpeas and maize soybeans intercropping benefit .

	Initial Soil status (ppm)	N residual after Cowpeas harvest (ppm)	N residual after Soybeans harvest (ppm)
Sole maize basal dressing only	23	23^{c}	24^{c}
legume sole crop	23	32^{bc}	40^{b}
Maize legume 1:1 row ratio	23	43^{ab}	47^{ab}
Maize legume 1:2 row ratio	23	27^{bc}	50^{ab}
Maze legume 1:3 row ratio	23	29^{bc}	39^{b}
Maize legume in one row	23	38^{abc}	39^{b}
Sole maize basal + 140 kg/ha N	23	49^{a}	56^{a}
Maize legume 1:1 row ratio + basal + 70 kg/ha N	23	32^{bc}	38^{bc}
Maize legume 1:2 row ratio + basal + 70 kg/ha N	23	39^{ab}	38^{bc}
Maize legume 1:3 row ratio + basal + 70 kg/ha N	23	49^{a}	47^{ab}
Mean	**23**	**36.1**	**41.8**
CV%		24.9	20.9
LSD		15	14.57
SE		2.85	0.971
P-value		0.024	0.012

legume plants. In maize/cowpea intercropping planting pattern did not affect 5 cob seed weight. Thayamini and Brintha (2010) noted that the planting pattern of the maize and legume did not affect the yield of maize while Thole (2007) and Ofori and Stern (1987) found yield of a component crop reduced by intercropping. Intercropping maize with cowpea was seen not to have a significant effect on 5 cob seed weight. Egbe et al.., (2010) noted different results when he found significant decreases in ear length, cob length, dry cob weight, dry grain yield and dry total plant biomass when maize was intercropped with cowpeas.

LAND EQUIVALENT RATIO

Intercropping wtd gave the same LER as intercropping td. Therefore intercropping wtd was beneficial. This is because legumes can relocate fixed nitrogen to intercropped cereals through their joint growing period and this nitrogen is an imperative resource for the cereal (Shen and Chu, 2004; Bhagah et al. 2006). Therefore application of nitrogen to intercropping could not benefit the crop significantly. Sole maize td gave significantly highest LER of 2.14 (p= 0.002). Competition among mixtures is thought to be a major factor affecting yield as compared with sole cropping of cereals (Ndakidemi 2006) especially when full amount of nitrogen is applied. This shows that when sole maize is given its nitrogen requirement, yield will be at its optimum. However in the second and third year maize cowpeas 1:1 intercrop td had significantly the highest LER 1.80; 1.78 at p= 0.006 and p=0.014 respectively. Intercropping maize/cowpeas 1:1 wtd in the second and third year gave LERs of 1.42 and 1.45 respectively. This showed that there was no benefit in top dressing an intercrop. In the first year maize/soybeans intercrop did not show any significant differences p=0.506. Combined analysis showed that there were significant differences obtained when maize/cowpeas were intercropped compared to sole cropping. Intercropping maize/cowpeas with top-dressing did not show differences to intercrop wtd. However, across season analysis of sole cropping maize with top-dressing showed significantly higher LER. A LER greater than 1 has been reported by Dahmardeh, (2010). Intercropping maize/soybeans showed significantly higher LER (1.65) in 1:2 wtd. Topdressing in a maize/soybean system 1:2 also showed significantly highest LER (1.85) which was more than the one wtd. This was so because a soybean crop must get a high amount of N to achieve high seed yields because of its high seed protein content (Sinclair and De Wit, 1976). Therefore the nitrogen that was applied benefited the soybeans crop. Willey (1979) noted that better use of recourses such as light, nutrients and water in an intercrop improved the yields in an intercrop.

Residual nitrogen

There were significant differences shown in the amount of N left in the soil after harvesting maize/cowpeas 1:1 wtd compared to sole maize wtd. There were also significant differences in the amount of N left in the soil after harvesting maize/soybeans 1:1; 1:2 and 1:3 wtd. Adeleke and Haruna (2012) also in the result of their findings revealed increase in total nitrogen after cropping any of the four legumes (soybean, cowpea, lablab and groundnut). This monumental increase in the total nitrogen was probably due to the ability of the legumes to fix atmospheric nitrogen in the soil through symbiotic N fixation. Kanton & Dennett, (2008) also found that the shorter more shaded legumes uses captured solar radiation efficiently in the intercrop than when grown alone. Dwivedi et al. (2015) found out that cereals are more competitive than the legume for soil mineral N, but the legume can fix N symbiotically. Intercropping 1:1 had more residual nitrogen compared to sole maize in maize/cowpea intercropping system. The nitrogen left in the soil as residual was fixed by cowpeas and soybeans.

The applied nitrogen contributed to the residual nitrogen left in the soil after harvesting because the maize crop could not fully utilize it. When nitrogen was applied to an intercrop the maize crop became more competitive for light, water and space affecting the legumes' productivity in terms of nitrogen fixation. The amount of residual nitrogen left in the soil ended up the same in maize td and wtd. This might have been due to the reduced radiation captured by legumes coupled with an inefficient use of the intercepted PAR resulting from the increasing canopy from maize (Kermah et al. 2017). Increasing the number of cowpea rows in an intercrop did not give significant increase in residual nitrogen wtd maize. However, when the intercropped maize received applied nitrogen 1:3 residual nitrogen was significantly higher compared to 1:1 td in maize/cowpeas intercrop. More residual nitrogen was recorded in soybeans intercropping compared to cowpeas maize intercropping. Maphumo (2011) concluded that soybean fixes more nitrogen compared to cowpeas.

CONCLUSION

Intercropping maize/cowpeas and maize/soybeans has shown advantages in both soil fertility and LER, particularly for maize. In a maize/soybean intercropping system 1:2 wtd was the best option whilst intercropping 1:1 in maize/cowpeas was the best option. Therefore there is no need to apply top dressing to an intercrop. Farmers can apply 140 kg/ha to a sole maize crop to optimize their yield when nitrogen is available. Soybeans give more residual nitrogen compared to cowpeas. The size of cobs and seeds were increased by intercropping of cowpeas and soybeans.

Recommendation

Intercropping maize/cowpea one row of cowpeas should be use under semi-arid conditions. Intercropping maize/soybeans two rows of soybeans should be used under these conditions. Farmers should not top-dress their crops when intercropping. When farmers are endowed with resources they can apply 140 kg/ha N to their sole crop of maize and get optimum yields. Soybeans leaves more residual nitrogen compared to cowpeas.

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