Sky Journal of Agricultural Research Vol. 5(1), pp. 001 - 014, January, 2016
Available online http://www.skyjournals.org/SJAR
ISSN 2315-8751 ©2016 Sky Journals

Full Length Research Paper

Faba bean precursor crop and N rates on subsequent yield components of maize in Toke Kutaye, western Ethiopia

Tolera Abera[1], Tolessa Debele[2], Ernest Semu[3], Dagne Wegary[4] and Haekoo Kim[4]

[1]Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center, Land and Water Resources Research Process, P.O. Box 382, Ambo, West Shoa, Oromia, Ethiopia.
[2]Wheat Project coordinator Support to Agricultural Research for Development of Strategic Crops in Africa (SARD-SC), ICARDA c/o ILRI P.O. Box 5689 Addis Ababa, Ethiopia.
[3]Department of Soil Science, Sokoine University of Agriculture, P. O. Box 3008, Chuo Kikuu, Morogoro, Tanzania.
[4]International Maize and Wheat Improvement Centre (CIMMYT), Global Conservation Agriculture Program, P O. Box 5689. Addis Ababa, Ethiopia.

Accepted 13 November, 2015

The biological N_2-fixation in faba bean on subsequent nitrogen fertilizer requirement of highland maize varieties would be useful in the guiding application of additional nitrogen fertilizer in cropping sequence. Significantly higher mean leaf area, leaf area index, plant height, grain yield, thousand seed weight, dry biomass and harvest index of maze were obtained following faba bean precursor crop with nitrogen application. Interaction of faba bean precursor crop with rhizobium inoculation by maize varieties and nitrogen fertilizer was significantly differed in all the maize characteristics measured. Interaction of faba bean precursor crop with rhizobium inoculation and maize varieties significantly affected mean leaf area and leaf area index of maize varieties. Maize planted following faba bean precursor crop without rhizobium inoculation produced significantly higher mean grain yield at full recommended nitrogen fertilizer. Significantly higher mean grain yield of maize was obtained from the application of half recommended nitrogen fertilizer following faba bean precursor crop with rhizobium inoculation. The planting of faba bean varieties with and without rhizobium inoculation was improved N status of the soil and nitrogen fertilizer response maize varieties. Production of maize varieties following faba bean precursor crop without and with rhizobium inoculation by the application of half recommended nitrogen fertilizer were recommended for sustainable maize production in highlands of western Ethiopia.

Key words: Precursor crop, rhizobium inoculation, N fertilizer, varieties.

INTRODUCTION

In Sub-Saharan Africa, agriculture could provide a relatively large share of the gross domestic product (GDP), but productivity in the sector lags considerably behind that of other continents, as well as behind the region's potential (Oluoch-Kosura, 2013). However, Vesterager et al. (2008) reported that land degradation, low soil fertility, limited and erratic rainfall with ever increasing population pressure is a very common feature of large parts of Sub-Saharan Africa which affects crop productivity. Approximately 50% of potentially arable land is currently under cultivation, of which 2000 million ha (23% of agricultural land) is already degraded and degradation of the remaining arable land continues due to mismanagement (UNEP, 2004). Soil degradation is occurring at an alarming rate and threatens soil productivity and maize production in western Oromia due to continuous cropping in last three decades. Conventional agriculture (continuous cropping with

*Corresponding author. E-mail: thawwii@yahoo.com, or thawwii2014@gmail.com.

inputs) has certain limitations in terms of maintaining long-term soil fertility (Charpentier et al., 1999). Longer cultivation has further depleted the soil organic-matter content and fertility (Wu et al., 2003). Crop rotation is the most among factors significantly increasing soil organic matters (Campbell et al., 1996). Legumes contribute to the maintenance and restoration of soil fertility by fixing N_2 from the atmosphere (Giller and Wilson, 1991). Furthermore, the use of leguminous green manures, crop rotation and intercropping is traditional, and the inputs from biological nitrogen fixation from these inputs often promote significant increase in subsequent grain or other crops. The input of fixed N from grain legumes may be a significant contributing factor in relation to sustaining productivity in smallholder systems (Sanginga, 2003). Faba bean can improve the economic value of a following crop by enhancing the yield (Lopez-Bellido et al., 1998). Wright (1990) also observed significant yield increase (12%) in the second cereal following faba bean compared to N fertilized continuous cereals. Faba bean incorporated field remarkable increased preceding maize yield and yield of 8.32 Mg ha^{-1} for maize seed was possible under no fertilization (Beslemes et al., 2013). El-Gizawy (2009) found significantly higher mean grain yield of maize was obtained after faba bean and suggested which might be due to enriching the soil with N and organic matter. Faba bean can make residual phosphorus available that otherwise would remain fixed (Nuruzzaman et al., 2005) and may indirectly make more phosphorus and potassium available for subsequent crops (KÖpke and Nemecek, 2010) and the rotational benefit of faba bean to improve the P availability for subsequent crops also is considered to be closely related to the mineralization of its P-rich crop residues rather than to residual effects of root exudates on soil chemistry.

Legumes in rotations also generally result in greater microbial activity and diversity in soils (Lupwayi and Kennedy, 2007) which may enhance the nutrient uptake and availability of soil nutrients. The increased grain yield maize varieties after faba bean precursor which might be due to change in soil organic matter with faba bean residue. El-Gizawy (2009) stated that faba bean residue was improved due to the physical, chemical and biological characters of the soil. Positive precrop effects of faba bean are predominantly the result of nitrogen made available by the pulses and substantially contributing to the nitrogen economy of the subsequent crops (Lo´ pez-Bellido et al., 1998; Turpin et al., 2002; Walley et al., 2007). Rochester et al. (2001) stated that faba bean may improve the structure of poorly structured soil by stabilizing soil aggregates and demonstrated the vigorous tap-roots of faba bean and other legumes can reduce the soil strength for a succeeding cotton crop compared to continuous cotton and cereals as pre-crops. Dyke and Prew (1983) reported that faba bean roots and stubble contributed 44 – 50 kg N ha^{-1} to the requirements of the following crop in a temperate climate. Faba bean produce high levels of rhizodeposition which will improve the soil N balance, assists in maintaining soil organic fertility, and appear to provide an important source of N for following crops in the rotation (Jensen et al., 2010). Loss et al. (1997) reported that faba bean is considered a promising precrop in cereal crop rotations on neutral to alkaline loam and clay soils of South Western Australia, which is true in highland areas of western Ethiopia. Faba bean has been deposited up to 100 kg N ha^{-1} of additional N being below-ground (Schwenke et al., 1998; Walley et al., 2007; Hauggaard-Nielsen et al., 2008). Walley et al. (2007) reported that a well-inoculated pulse crop can fix sufficient quantities of N to eliminate the need for N fertilizer inputs for subsequent cereals. The extent to which a legume crop can benefit a subsequent crop depends on the quantity of N the legume fixed and N which is incorporated into the soil and the rate and time-span of decomposition of residues and synchrony with nutrient need of the subsequent crop and its efficiency of N utilization (Giller et al., 1998). Safeguarding of the soil fertility at the economic optimum level with appropriate crop rotation and affordable fertilizer rate is essential for sustainable maize production in the region. Identification of suitable crop rotation with optimum fertilizer was more reliable and usually maximize maize grain yield. Therefore, the objective was to determine the effects of faba bean precursor crop and N rate on subsequent yield components of maize in Toke Kutaye western Ethiopia.

MATERIALS AND METHODS

The experiments were conducted during the 2013 and 2014 cropping seasons on two farmers' fields in the humid highlands of Toke Kutaye in Oromia National Regional State, western Ethiopian. The area lies between 8^{o}98'N latitude and 37^{o}72'E longitude, at an altitude of 2262 and 2322 meter above sea level, with mean annual rainfall of 1045 mm (Table 1) (NMSA, 2014). It has a cool humid climate with the mean minimum, mean maximum and average air temperatures of 8.9, 27.4 and 18.1°C respectively.

The soil sample was collected at a depth 0 - 20 cm with augur three times, first, before application of the treatment (2013), second after harvesting of the rotation crops when the field was ready for maize planting in 2014. Third, soil sample was collected after harvesting of maize from three plots and composited one for each treatment. Determination of soil particle size distribution was carried out using the hydrometer method (Dewis and Freitas, 1984). Soil pH was measured using digital pH meter in 1:2.5 soil to solution ratio with H_2O. Exchangeable basis were extracted with 1.0 Molar ammonium acetate at pH 7. Ca and Mg in the extract were measured by atomic absorption spectrophotometer while Na and K were determined using flame photometry (Van Reeuwijk, 1992). Cation exchange capacity of the

Table 1. Long term rainfall and temperature data for the Toke Kutaye sites as obtained from nearby weather stations.

Year	Rainfall (mm)												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
1990-2008	38.5	17.46	49.7	89.35	93	155.45	247.4	172	96.4	46.45	11.2	13.9	1031
2009	55.6	49.2	58.7	139.2	62.9	142.8	292.4	102.2	112.0	27.2	13.0	16.0	1071
2010	0.0	0.0	68.6	110.2	154.5	285.8	175.4	109.4	115.1	0.0	34.3	9.6	1063
2011	7.1	9.9	44.4	93.0	123.1	270.3	306.1	218.5	118.6	3.6	18.6	0.0	1213
2012	0.0	0.0	0.0	8.6	0.0	241.0	318.4	148.7	117.2	4.6	20.0	0.0	859
2013	0.0	0.3	37.0	160.3	176.8	141.8	225.6	87.5	128.7	77.2	17.2	4.0	1056
2014	0	0.2	27.0	99.5	152.0	185.0	245.6	147.0	125.0	22.0	15.0	3.0	1021
Mean	14.5	11.0	40.8	100.0	108.9	203.2	258.7	140.8	116.1	25.9	18.5	6.6	1045
Temperature (°C)													Mean
Minimum	6.8	7.4	9.2	9.5	9.7	10.8	10.8	10.4	9.3	6.3	6.3	6.7	8.9
Maximum	26.9	27.3	27.9	27.6	28.5	28.0	27.0	26.3	26.5	26.6	26.8	27.2	27.4
Mean	16.9	17.4	18.6	18.6	19.1	19.4	18.9	18.4	17.9	16.5	16.5	16.9	18.1

soil was determined following the modified Kjeldahl procedure (Chapman, 1965) and reported as CEC of the soil. Percent base saturation was calculated from the sum of exchangeable basis as a percent of the CEC of the soil. Exchangeable acidity was determined by extracting the soil samples with M KCL solution and titrating with sodium hydroxide as described by McLean (1965). Organic carbon was determined following wet digestion methods as described by Walkley and Black (1934) whereas kjeldahl procedure was used for the determination of total N as described by Jackson (1958). The available P was measured by Bray II method (Bray and Kurtz, 1945). The electrical conductivity was estimated from saturated extracts of soil samples. The steam distillation method was used for determination of NO_3 and NH_4 as described by (Keeney and Nelson, 1982).

The experiments were laid in the Randomized Complete Block Design in factorial arrangement with three replications. The factorial arrangement were faba bean variety (Moti) with and without rhizobium strain inoculation as factor A, maize varieties (Wenchi and Jibat) as factor B and three nitrogen rate as factor C. The rhizobium strain (FB-1035 which was released by Land and Water Resources Research Process of Holetta Agricultural Research Center) was used for inoculation of faba bean seed receiving inoculation.

The faba bean (variety Moti) without and with rhizobia inoculation was planted in the 2013 cropping season as precursor crop. In the second year (2014), two maize varieties were sown with three levels of nitrogen. Twelve treatment combinations were imposed with the main crop (maize). For precursor crop (faba bean) recommended seed rate 200 kg ha^{-1} and fertilizer rate of 18/20 NP kg ha^{-1} were used. During the 2014 cropping season, maize hybrid (Wenchi and Jibat) were sown with three levels of fertilizers (0, half recommended (55 kg N ha^{-1} and recommended (110 kg N ha^{-1}) rate for the area.

The total gross plot size was 5.1 x 4.5 m with 3 x 5.1m net plots. The spacing was 75 x 25 cm. The seed rate used for maize was 25 kg ha^{-1}. Sowing dates followed recommended date of planting ranged April 15 - 30. Full dose of phosphorus (as DAP) was applied once at planting, while nitrogen (as Urea) was applied in spilt doses, half at planting and the remaining half applied 30 to 40 days after planting. All other agronomic management practices were applied as per recommendation for the variety. The necessary data were collected at the right time and crop growth stage. Data were collected on dry biomass, 1000 seed weight, grain yields as kg ha^{-1} and harvest index at maturity of maize and after harvesting. The harvested grain yield was adjusted to 12.5 % moisture level (Birru, 1979 and Nelson et al., 1985) and converted to grain yield as kilogram per hectare.

The data analyses for agronomic data were carried out using statistical packages and procedures of SAS computer software (SAS, 2010). Mean separation was done using least significance difference (LSD) procedure at 5 % probability level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Soil physical and chemical concentration of the experimental site

The soil types of the experimental site are Alfisol (FAO, 2007). The soil properties of the two sites are indicated in Table 2. The soil analysis results of the two farms before planting of faba bean and the main crop (maize) planting are indicated (Table 2). The texture of the soil was clay and clay loam. The soil pH in H_2O ranged from 4.36 to 5.77 for farm 1 and farm 2 which were found in very strongly acidic to moderately acidic (Landon, 1991). Faba bean planting without and with rhizobia inoculation significantly improved the soil pH of the two farms. Faba

Table 2. Some soil physical and chemical concentration before main crop (maize) at Toke Kutaye districts, western Ethiopia.

Soil parameters	Farm 1			Farm 2		
	Before faba bean	Faba bean + 0 RI	Faba bean + 10 g RI kg seed $^{-1}$	Before faba bean	Faba bean + 0 RI	Faba bean + 10 g RI kg seed $^{-1}$
pH (1:2.5)	4.4	5.57	5.77	4.36	5.05	5.66
P (ppm	5.43	4.76	8.21	6.69	4.99	4.97
TN (%)	0.25	0.19	0.17	0.16	0.22	0.23
OC (%)	2.42	2.22	1.91	2.49	2.57	2.46
OM (%)	4.16	3.82	3.29	4.28	4.42	4.23
CEC (meq/100g)	18.5	25.93	27.78	19.44	23.85	25.57
k (meq/100g)	0.28	0.7	0.84	0.14	1.41	1.46
Exch.(meq/100g)	0.35	0.18	0.15	0.42	0.23	0.18
$N0_3^-N$ (ppm)	55.64	71.4	46.2	2.43	64.4	53.2
NH_4^+N (ppm)	23.43	40.6	19.6	2.92	39.2	21
Texture	clay loam	clay loam	clay loam	Clay	clay	clay

Farm 1= Gadisa Beksisa, Farm 2= Sisay Belete.

bean planting without and with rhizobia inoculation improved soil pH by 26.59 and 15.85 %; and 31.14 and 29.82 % for farm 1 and farm 2, respectively. Similarly, Tolera et al. (2009) observed that crop rotation and N-P amendment significantly increased pH of the soil.

Total N ranged from 0.17 to 0.0.25% in farm 1 and 0.16 to 0.23% in farm 2. The total N concentrations of the two farms were in the low to medium range (FAO, 1990; and Landon, 1991). The total nitrogen concentration of farm 2 was increased from before plating by 37.5 and 43.75 % from planting faba bean without and with rhizobia inoculation. This might be attributed to biological nitrogen fixation of faba bean. Similarly, Kumar et al. (1983); and Holford and Crocker (1997) reported that legumes in crop rotation improves soil fertility, particularly soil N content. A cumulative enhancement of the N-supplying power of the soil in wheat-lentil rotation was reported by Campbell et al. (1992) and; in maize haricot bean rotation by Tolera et al. (2009). The increase in total N following faba bean helps to reduce the amount of N required to optimize maize yield.

The soil $N0_3^-N$ concentration was ranged between 46.2 to 71.4 ppm in farm1 found in high range; and 2.43 to 64.4 ppm for farm 2, found in low to high range (FAO, 2006); and high to excessive (Marx et al., 1999). Planting of faba bean was improved $N0_3$.N by 20.43 and 2089%; without rhizobium inoculation; and 54.55 and 2550% with rhizobium inoculation from farm 1 and farm 2 as compared to before planting result. This implies that the use of faba bean with and without rhizobium inoculation significantly contributed to biological nitrogen fixation which was left in the field and used for the next crops. The soil NH_4-N concentration was 19.6 to 40.6 ppm for farm 1 and found in high range; and 2.92 to 39.2 ppm in farm 2 found in optimum to high range (Marx et al., 1999). Horneck et al. (2011); and Marx et al. (1999) reported that ammonium-nitrogen concentrations of 2 - 10 ppm are typical. The soil NH_4^+N concentration was increased by 19.54 and 1243 %; and 107 and 619 % with planting faba bean without and with rhizobium inoculation as compared to before planting from farm 1 and farm 2 (Table 2). Faba bean can maintain high rates of BNF in the presence of high amounts of available N in the soil (Schwenke et al., 1998; and Turpin et al., 2002), a fact that can be attributed to its low rooting density and rooting depth compared with other pulses and most notably fodder legumes (KÖpke and Nemecek, 2010). Increased concentrations of inorganic N in the soil profile after faba bean cropping can result from “spared N” remaining in the soil as a result of a relatively inefficient recovery of soil mineral N compared to other crops (Turpin et al., 2002). The amounts of NO3-N and NH4-N concentration of the soils were significantly higher due to planting of faba bean without and with rhizobium inoculation. Planting faba in cropping sequence without rhizobium inoculation where farm history was showed faba bean production in the area and with rhizobium inoculation where faba bean new for the area is the key in solving the soil N fertility status for maize production and reduce green gas effects of nitrogen to the environment and secure sustainable maize production and food security.

Available P ranged from 5.43 to 8.21 and 4.97 to 6.69 ppm, which was in the low to medium range (FAO, 1990; and Landon (1991). This relatively low P can be attributed to the high phosphorous fixing capacity of the acid soil. In farm 1, planting of faba bean with rhizobia inoculation improved the available P by 51.20 and 72.48% as compared to before planting and planting of faba bean without rhizobia inoculation. In farm 2, planting of faba bean without and with rhizobia inoculation reduced the amount of available P by 25.41 and 25.71 %.

Organic carbon and organic matter contents of the soil ranged from 1.91 to 2.57 and 2.46 to 257%, and 3.29 to 4.16 and 4.23 to 4.42% in farm 1 and 2 respectively (Table 2), which are in the low to medium range (FAO, 1990; and Landon (1991). The exchangeable K contents of the soil ranged from 0.28 to 0.84 and 0.14 to 1.46 meq

Table 3. Mean square of leaf area, leaf area index and plant height of maize due to rhizobium inoculation, variety and nitrogen rate around Toke Kutaye, western Ethiopia.

Source of variation	DF	Mean square					
		Leaf area plant-1 (cm2)		Leaf area index		Plant height (cm)	
		Farm-1	Farm-2	Farm-1	Farm-2	Farm-1	Farm-2
Replication	2	101673.982	1112998.636	0.02892060	0.31658628	2088.160000	130.0677778
Rhizobium inoculation (RI)	1	223914.691	318576.051	0.06369129	0.09061719	3.867778	456.5344444
Varieties (V)	1	6.021	3554822.717	0.00000171	1.01114957	106.090000	40.5344444
Nitrogen (N)	2	3072390.621*	732403.228	0.87392444*	0.20832803	2980.693333*	295.3344444
RI X V	1	2871021.012*	1170403.930	0.81664598*	0.33291490	623.334444	58.2677778
RI X N	2	309329.196	553164.068	0.08798697	0.15734445	346.137778	341.4011111
V X N	2	68572.060	1735224.040	0.01950494	0.49357484	1184.493333	165.2011111
RI X VXN	2	1432909.084	2351466.659	0.40758303	0.66886163	707.604444	95.0011111
Error	22	566251.33	919093.45	0.16106704	0.26143103	710.00727	447.69202
CV (%)		13.33	16.18	13.33	16.18	10.57	9.81
Replication	2	101673.98	1112998.64	0.02892060	0.31658628	2088.16000	130.067778
Treatments	13	1169213.06	1435301.70	0.33257616	0.40826359	1015.55909	213.564747
Error	26 (46)	566251.33	919093.45	0.16106704	0.26143103	710.00727	447.69202
CV (%)		13.33	16.18	13.33	16.18	10.57	9.81

*= Significant at 5 % probability level.

Table 4. Mean square of grain yield, thousand seed weight, dry biomass and harvest index of maize due to rhizobium inoculation, variety and nitrogen rate around Toke Kutaye, western Ethiopia.

Source of variation	DF	Mean square							
		Grain yield (kg ha-1)		Thousand seed weight (g)		Dry biomass(kg ha-1)		Harvest index (%)	
		Farm-1	Farm-2	Farm-1	Farm-2	Farm-1	Farm-2	Farm-1	Farm-2
Replication	2	9553430.10	53316.38	975.35441	1430.6612	38363824.9	3682965.00	198.593923	5.3134176
Rhizobium inoculation (RI)	1	2573984.31	880809.06	776.45982	59.60428	35869399.7	2416365.26	2.5452007	15.401145
Varieties (V)	1	323137.15	1152645.83	45.43787	14156.56*	343985309*	3866064.10	287.51454*	127.78954*
Nitrogen (N)	2	16190746.6*	5351309.37*	4051.282*	1601.1606	88038138.2	31202217*	232.05037*	22.737253
RI X V	1	36997.93	2393203.80	1125.8108	1926.8922	45466961.9	16660269*	53.2619898	6.3882149
RI X N	2	2057277.03	272548.80	533.40079	443.12035	19376028.2	6977979.74	57.7262133	6.4480072
V X N	2	3159448.25	1510045.44*	564.87111	1693.8261	15906451.0	10189294*	18.8789580	46.790789*
RI X VXN	2	6834685.74	241763.88	5176.235*	606.87493	141888509.	2340534.98	15.7759639	12.713543
Error	22	2573531.5	296691.63	965.19789	1313.3056	64465001	606.87493	35.556253	14.495112
CV (%)		22.11	12.30	7.99	9.71	24.46	11.65	25.84	12.40
Replication	2	9553430.10	53316.38	975.35441	1430.6612	38363824.9	3682965.0	198.593924	5.3134176
Treatments	13	5401675.87*	1743453.97	2054.4807	1313.3056	86885447.7	11305705*	90.198613*	14.495112
Error	26	2573531.5	296691.63	965.19789	1313.3056	64465001	2837931.3	35.556253	14.495112
CV (%)		22.11	12.30	7.99	9.71	24.46	11.65	25.84	12.40

*= Significant at 5 % probability level.

100 g-1 (Table 2), which are in the low to medium and low to high range, respectively. The CEC of the soil ranged 18.5 to 27.78 and 19.44 to 25.57 Meq 100 g-1 of soil (Table 2), which is in the medium to high range (FAO, 1990; and Landon (1991). These soils have medium nutrient holding capacity level, water holding capacity, less susceptible to leaching, losses of Mg2+ and K+ and medium organic matter contents for crop production.

Leaf area, leaf area index and plant height of maize

The summarized analysis mean results of leaf area, leaf area index and plant height of maize are indicated in Tables 3, 5, 6 and 7. Main effects of rhizobium strain and varieties were non-significantly affected by mean leaf area, leaf area index and plant height of maize varieties. This indicates the use of rhizobium strain alone to faba bean precursor crop and maize varieties does not have any influence on mean leaf area, leaf area index and plant height maize. Mean leaf area, leaf area index and plant height of maize were significantly affected by the application of nitrogen on farm 1 and combined mean (Table 6). Significantly, higher mean leaf area and leaf area index of maize were measured from application half

Table 5. Mean square of combined leaf area, leaf area index, plant height, grain yield, thousand seed weight, dry biomass and harvest index of maize due to rhizobium inoculation, variety and nitrogen rate around Toke Kutaye, western Ethiopia.

Source of variation	DF	Mean square						
		leaf area plant-1 (cm2)	Leaf area index	Plant height (cm)	Grain yield (kg ha-1)	Thousand seed weight (g)	Dry biomass(kg ha-1)	Harvest index (%)
Replication	2	818550.095	0.232832	684.52056	7264739.4	1909.18237	16035259	139.350275
Rhizobium inoculation (RI)	1	4161.380	0.001184	272.22222	221678.0	202.90341	803879	18.028476
Farm (FM)	1	1394970.532	0.396791	24038.9356*	143902656.7*	4188.97680*	6805555556*	1923.7266*
Varieties (V)	1	1782040.728	0.50689	7.73556	1348188.7	6298.97294*	321220129*	928.967318*
Nitrogen (N)	2	3252318.646*	0.925104*	2491.32056*	19135053.4*	5352.76500*	74234698	177.784435
FM X RI	1	538329.362	0.153125	188.18000	3233115.4	633.16069	57354617	42.278437
FM X V	1	1772788.010	0.504260	138.88889	127594.3	7903.02262*	68999255	42.239618
FM X N	2	552475.203	0.157149	784.70722	2407002.5	299.67845	62919055	109.684032
RI X V	1	3853812.107*	1.096195*	531.38000	1512663.6	2999.21142	43474257	15.484340
RI X N	2	155377.215	0.044196	628.10389	1648086.6	339.03316	20377825	45.271173
V X N	2	1006865.268	0.286397	1101.12389	4460471.9	1152.68830	29005091	8.619361
RI X VXN	2	3597262.327*	1.023221*	142.15167	2252781.3	4615.16087*	66174223	62.805627
FM X RI X VXN	7	509990.490	0.145064	298.16302	1763771.0	839.48332	28346451	46.133648
Error	46	727605.00	0.20696320	620.36519	2995450.8	1111.3205	38832130	68.132526
CV (%)		14.74	14.74	10.65	21.54	8.75	24.24	19.37
Replication	2	818550.09	0.23283203	684.52056	4769875.8	1909.18237	27259933	130.285652
Treatments	13	1969423.74*	0.5601916*	866.97616	5279574.2*	2947.30749*	53384182	93.583056*
Farm (FM)	1	1394970.53	0.39679162	24038.93556*	143902656.7*	4188.97680*	6068347222*	1046.694399*
Error	46	727605	0.20696320	620.36519	1583014.1	1111.3205	32831266	27.138552
CV (%)		14.74	14.74	10.65	21.54	8.75	24.24	19.37

*= Significant at 5 % probability level

Table 6. Effects of rhizobium inoculation, variety and nitrogen rate on mean leaf area, leaf area index and leaf height of maize around Toke Kutaye, western Ethiopia.

Rhizobium inoculation(g)	Leaf area (cm^2)			Leaf area index			Plant height (cm)		
	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean
0	5726	5831	5779	3.05	3.11	3.08	252	212	232
10 g kg-1 seed	5568	6020	5794	2.97	3.21	3.09	253	219	236
Control	4678	4885	4782	2.69	2.52	2.61	232	213	223
LSD (5 %)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	13.33	16.18	14.74	13.33	16.18	14.74	10.56	9.81	10.65

Table 6 Cont.

Variety									
Wenchi	5648	6240	5944	3.01	3.33	3.17	254	215	234
Jibat	5647	5611	5629	3.01	2.99	3.00	251	217	234
LSD (5 %)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	13.33	16.18	14.74	13.33	16.18	14.74	10.56	9.81	10.65
N (kg ha-1)									
0	5063	5668	5365	2.70	3.02	2.86	236	212	224
55	5934	6160	6047	3.16	3.29	3.23	267	221	244
110	5944	5949	5947	3.17	3.17	3.17	253	214	233
Wenchi	4678	4885	4782	2.69	2.52	2.61	232	213	223
LSD (5 %)	637.1	NS	495.65	0.3398	NS	0.2643	22.56	NS	14.473
CV (%)	13.33	16.18	14.74	13.33	16.18	14.74	10.56	9.81	10.65

Farm 1-Farm 2= two farmers field (Gadisa Beksisa and Sisay Belete), NS=Non-significant difference at 5 % probability level.

Table 7. Combination effects of rhizobium inoculation, variety and nitrogen rate on mean leaf number, leaf area index and plant height of maize around Toke Kutaye, western Ethiopia.

RI g + MV + N kg ha^{-1}	Leaf area (cm2)			Leaf Area index			Plant height (cm)		
	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean
0+W +0	5602	6931	6267	2.99	3.70	3.34	251	214	233
0+W +55	6231	6381	6306	3.32	3.40	3.36	265	211	238
0+W +110	6193	5665	5929	3.30	3.02	3.16	232	204	218
0+J +0	4472	4707	4589	2.38	2.51	2.45	230	215	223
0+J + 55	5635	5560	5597	3.01	2.97	2.99	258	217	238
0+J +110	6223	5743	5983	3.32	3.06	3.19	275	211	243
10 +W +0	4496	5815	5156	2.40	3.10	2.75	243	214	229
10 +W +55	5503	5831	5667	2.93	3.11	3.02	275	232	253
10 +W +110	5860	6814	6337	3.13	3.63	3.38	257	213	235
10 +J +0	5681	5216	5449	3.03	2.78	2.91	219	205	212
10 +J + 55	6368	6867	6618	3.40	3.66	3.53	272	225	249
10 +J +110	5502	5573	5537	2.93	2.97	2.95	248	227	238
Wenchi	5199	4478	4839	2.69	2.52	2.61	238	204	221
LSD (5 %)	1274.2	1623.4	991.3	0.6796	0.8658	0.5287	45.12	NS	28.94
CV (%)	13.33	16.18	14.74	13.33	16.18	14.74	10.57	9.81	10.65

Farm 1-Farm 2= two farmers field (Gadisa Beksisa and Sisay Belete), RI= rhizobium inoculation, MV= maize varieties, W and J= Wenchi and Jibat maize variety, NS=Non-significant difference at 5 % probability level.

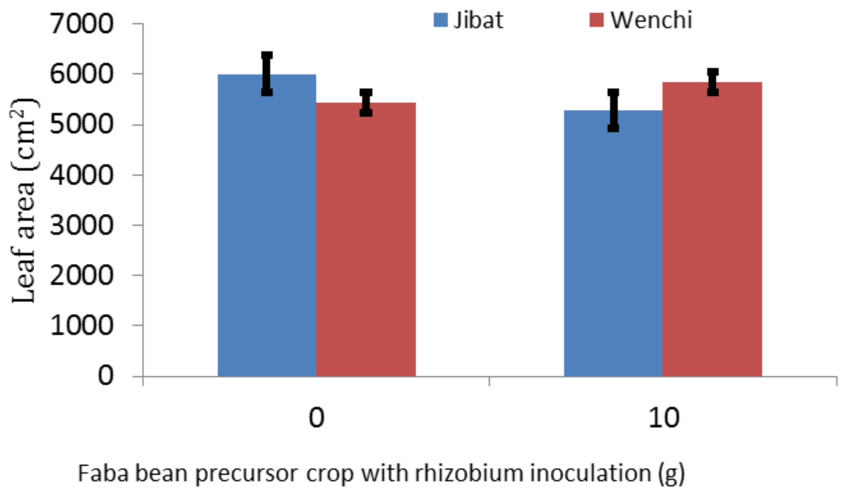

Figure 1. Interaction of effects of faba bean precursor crop with rhizobium inoculation and maize varieties on leaf area on farmer's field around Toke Kutaye, western Ethiopia.

(55 kg N ha-1) recommended nitrogen fertilizer. Application of half recommended nitrogen fertilizer produced higher leaf area of 1.68, 12.71 and 26.45% as compared of maize variety planted with recommended nitrogen fertilizer and with nitrogen fertilizer after precursor crop and continuous cropping maize. Significantly, higher mean leaf area index and plant height of maize were obtained from maize planted with half recommended nitrogen fertilizer. This revealed that the use of faba bean precursor crop could contribute better for nitrogen fertilizer requirement of sustainable maize production. Mean leaf area index advantages of 1.68, 12.71 and 26.45 % were obtained from maize planted with half recommended nitrogen fertilizer as compared to maize variety planted with recommended nitrogen fertilizer and with nitrogen fertilizer after precursor crop and continuous cropping maize. This indicates that application optimum nitrogen fertilizer following precursor crop has played a significant role in leaf area development and plant height maize. Therefore, reducing the amount of nitrogen fertilizer following faba bean precursor crop could be a desirable option for sustainable maize production.

Interaction effects of rhizobium strain with maize varieties and nitrogen fertilizer rates significantly affected mean leaf area, leaf area index and plant height of maize (Tables 5 and 7). The mean leaf area of maize varieties was ranged between 4839 to 6612 cm2. Maize varieties planted following faba bean precursor crop with and without nitrogen fertilizer produced higher leaf area and leaf area index as compared to continuous maize without nitrogen fertilizer application. Maize planted on farm 2 produced higher leaf area and leaf area index as compared to maize planted on farm 1, indicating there are variations of farmers' fields in fertility status and other management and environmental factors. Maize varieties planted following faba bean precursor crop with half and recommended nitrogen fertilizer application produced higher leaf area and leaf area index as compared to without nitrogen fertilizer application. This revealed the importance of integrated use of different soil management factors for sustainable maize production. Plant height of maize varieties was varied between farms and integrated use of different soil managements. Wenchi maize variety gave higher plant height of 253 cm with the application of half recommended nitrogen fertilizer following faba bean precursor crop with rhizobium strain inoculation (Table 7).

Interaction of effects of faba bean precursor crop with rhizobium inoculation and maize varieties on leaf area and leaf area index (Figures 1 and 2). Faba bean precursor crop without rhizobium inoculation produced significantly higher mean leaf area and leaf area index of maize varieties (Figures 1 and 2). Mean leaf area and leaf area index of maize varieties were equivalent following faba bean planted with rhizobium inoculation (Figures 1 and 2). Jibat maize variety were produced with higher leaf area and leaf area index following faba bean precursor crop without rhizobium inoculation and Wenchi following faba bean precursor crop with rhizobium inoculation. Faba bean precursor crop was created in variation with nitrogen status of the soil.

Grain yield, thousand seed weight, dry biomass and harvest index of maize

Mean grain yield of maize was non-significantly affected by following rhizobium application and variety after precursor crop (Tables 4, 5 and 8). Maize planted following rhizobium strain applied faba bean was produced 111 kg ha-1 mean grain yield advantage over maize planted following faba bean planted without

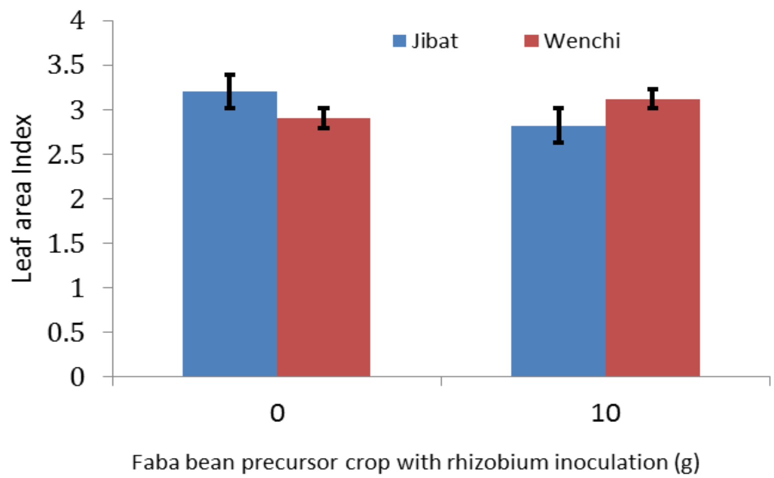

Figure 2. Interaction effects of faba bean precursor crop with rhizobium inoculation and maize varieties on leaf area index of maize on farmer's field around Toke Kutaye.

Table 8. Effects of rhizobium inoculation, variety and nitrogen rate on mean grain yield and thousand seed weight of maize around Toke Kutaye, western Ethiopia.

Rhizobium inoculation (g)	**Grain yield (kg ha^{-1})**			**Thousand seed weight (g)**		
	Farm 1	**Farm 2**	**Mean**	**Farm 1**	**Farm 2**	**Mean**
0	6988	4585	5787	393	372	383
10 g kg^{-1} seed	7523	4272	5898	384	375	379
Control	5596	30914	4344	341	337	339
LSD (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	22.11	12.30	29.62	7.99	9.71	8.75
Variety						
Wenchi	7351	4607	5979	390	354	372
Jibat	7161	4249	5705	387	393	390
LSD (5 %)	NS	NS	NS	NS	25.052	15.816
CV (%)	22.11	12.30	29.62	7.99	9.71	8.75
N (kg ha-1)						
0	5934	3804	4869	367	360	364
55	7718	4349	6034	397	377	387
110	8115	5132	6624	401	382	392
Wenchi	5596	30914	4344	341	337	339
LSD (5 %)	1358.2	461.17	1005.7	26.304	NS	19.371
CV (%)	22.11	12.30	29.62	7.99	9.71	8.75

Farm 1-Farm 2= two farmers field (Gadisa Beksisa and Sisay Belete), NS=Non-significant difference at 5% probability level.

rhizobium strains. Maize planted preceding faba bean without and with rhizobium inoculum was given mean grain yield advantage of 33.22 and 35.77% as compared to continuous maize indicating significant role of precursor faba bean on soil N improvement. Similar result was reported by Lopez-Bellido et al. (1998); and Wright (1990). In addition, the result was in agreement with Badr (1999); and Shams (2000) found grain yield of maize following faba bean increased as compared to cereals. Faba bean incorporated field remarkable increased preceding maize yield and yield of 8.32 Mg ha-1 for maize seed was possible under no fertilization (Beslemes et al., 2013). Similarly, El-Gizawy (2009) found significantly higher mean grain yield of maize was obtained after faba bean and suggested which might be due to enriching the soil with N and organic matter. Therefore, faba bean precursor crop could improve the economic value of following maize varieties.

Application of nitrogen fertilizer following faba bean precursor crop was significantly affected by mean grain yield of maize (Tables 4, 5 and 8). Significantly, higher mean grain yield of maize were collected from maize planted with application full recommended nitrogen fertilizer following faba bean precursor crop on farm 1

Table 9. Combination effects of rhizobium inoculation, variety and nitrogen rate on mean grain yield and thousand seed weight of maize around Toke Kutaye, Western Ethiopia.

RI g + MV + N kg ha^{-1}	Grain yield (kg ha^{-1})			Thousand seed weight (g)		
	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean
0+W +0	6201	3733	4967	368	329	348
0+W +55	8514	4554	6534	427	368	398
0+W +110	7038	5231	6135	371	338	355
0+J +0	5073	4225	4649	364	400	382
0+J + 55	6116	4139	5128	390	387	388
0+J +110	9588	5627	7607	439	411	425
10 +W +0	6375	3990	5182	379	330	354
10 +W +55	8176	5302	6739	377	372	374
10 +W +110	8399	4835	6617	417	384	401
10 +J +0	6688	3267	4977	360	383	371
10 +J + 55	8065	3403	5734	396	383	389
10 +J +110	7437	4836	6136	376	396	386
Wenchi	5596	3214	4405	341	387	364
LSD (5%)	2716.4	922	1462.2	52.61	61.36	38.742
CV (%)	22.11	12.30	21.54	7.99	9.71	8.75

Farm 1-Farm 2= two farmers field (Gadisa Beksisa and Sisay Belete), RI=Rhizobium inoculation, MV= maize varieties, W and J= Wenchi and Jibat maize variety, NS=Non-significant difference at 5 % probability level.

and 2 (Table 8). Similarly, El-Gizawy (2009) found that application of nitrogen fertilizer significantly affected mean grain yield of maize and higher N rate (120 kg N fed-1 was more effective in increasing grain yield of maize. Similar result was reported by (Gungula et al., 2005). Mean grain yield advantages of 5.14, 28.26 and 45.01 % from farm1; 18, 34.91 and 66% from farm 2; and 9.79, 36.04 and 52.50% combined mean were obtained from maize planted with recommended nitrogen fertilizer as compared without and half recommended nitrogen fertilizer application following faba bean precursor crop and continuous maize without nitrogen fertilizer application. Beslemes et al. (2013) found maize grain yield following faba bean green was increased in response to nitrogen application and modest application produced higher grain yield of maize. This indicates that applications of nitrogen fertilizers were necessary following legume precursor crop for sustainable maize production in the region.

Mean thousand seed weight of maize was non-significantly affected following faba bean precursor crop with and without rhizobium strain, but significantly affected by main effects of maize variety on farm 2 and combined mean; and nitrogen fertilizer application on farm 1 and combined mean (Table 8). Jibat maize variety gave higher thousands of seed weight as compared to Wenchi indicating variation of seed size with different maize variety. Combined mean thousand seed weight of 339, 364, 384 and 392 were collected from continuous maize without nitrogen fertilizer; and maize planted following faba precursor crop without, half and full recommended nitrogen fertilizer application. This indicates that application of nitrogen fertilizer plays a role for seed size of Jibat and Wenchi varieties of maize.

Mean dry biomass and harvest index of maize was non-significantly affected by main effects of following faba bean with and without rhizobium strain inoculation (Tables 4, 5, 10 and 11). Pare et al. (1993) was able to demonstrate that maize whole-plant dry matter yields were enhanced in the third corn crop following faba bean as compared to continuous maize. Significant difference of mean dry biomass of maize was observed due to maize varieties used on farm 1 and combined mean (Table 10). Significantly, higher mean dry biomass of maize was collected from Jibat variety as compared to Wenchi. This indicates different varieties were varied in biomass accumulation of above ground plant parts. Nitrogen fertilizer application on farm 1 was significantly affected mean dry biomass of maize. Higher mean dry above ground biomass of maize was harvested from the application of half recommended nitrogen fertilizer as compared without and full recommended nitrogen fertilizer applications.

Mean harvest index of maize was varied between varieties of maize planted following faba precursor crop (Tables 4, 5 and 10). Significantly higher mean harvest index of maize was obtained from Wenchi as compared to Jibat variety. This revealed there was variation between varieties of maize in grain yield to biological yield ratio. Application of nitrogen fertilizer rates were significantly affected mean harvest index of maize on two farms and combined over farms to significantly higher mean harvest index was produced from maize varieties planted following precursor crops with recommended nitrogen fertilizer as compared to others. Therefore,

Table 10. Effects of rhizobium inoculation, variety and nitrogen rate on mean dry biomass and harvest index of maize around Toke Kutaye, western Ethiopia.

Rhizobium inoculation (g)	Dry biomass (kg ha^{-1})			Harvesting index (%)		
	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean
0	31826	14722	23274	23.34	31.36	27.35
10 g kg^{-1} seed	33822	14204	24013	22.81	30.05	26.43
Control	22381	11632	17006	17.52	26.19	21.86
LSD (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	24.46	11.65	26.97	25.84	12.40	29.22
Variety						
Wenchi	29733	14135	21934	25.91	32.59	29.25
Jibat	35915	14790	25353	20.25	28.82	24.54
LSD (5 %)	5550	NS	2956.5	4.1221	2.6319	3.9162
CV (%)	24.46	28.59	26.97	25.84	30.05	29.22
N (kg ha^{-1})						
0	31414	13045	22229	19.12	29.27	24.19
55	35947	14127	25037	22.31	30.84	26.58
110	31111	16217	23664	27.81	32.01	29.91
Wenchi	22381	11632	17006	17.52	26.19	21.86
LSD (5 %)	NS	1426.3	NS	5.0485	1426.3	NS
CV (%)	24.46	28.59	26.97	25.84	30.05	29.22

Farm 1-Farm 2= two farmers field (Gadisa Beksisa and Sisay Belete), NS=Non-significant difference at 5 % probability level.

Table 11. Combination effects of rhizobium inoculation, variety and nitrogen rate on mean dry biomass and harvest index of maize around Toke Kutaye, Western Ethiopia.

RI g + MV + N kg ha^{-1}	Dry biomass (kg ha^{-1})			Harvesting index (%)		
	Farm 1	Farm 2	Mean	Farm 1	Farm 2	Mean
0+W +0	20237	11222	15729	30.64	33.27	31.58
0+W +55	30126	11922	21024	28.26	38.20	31.08
0+W +110	19403	13471	16437	36.08	38.83	37.46
0+J +0	33206	11483	22345	15.37	36.37	25.87
0+J + 55	36013	13379	24696	16.92	30.87	23.90
0+J +110	35131	17103	26117	28.13	33.46	30.80
10 +W +0	27019	12033	19526	23.30	33.55	28.42
10 +W +55	32555	13549	23052	25.50	39.66	32.58
10 +W +110	31842	12736	22289	28.26	38.06	33.16
10 +J +0	33328	10780	22054	19.84	31.24	25.54
10 +J + 55	38969	11179	25074	20.93	30.71	25.82
10 +J +110	31000	13637	22319	25.62	35.61	30.62
Wenchi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LSD (5 %)	13596	2852	6658.9	10.097	6.4468	6.0542
CV (%)	24.46	11.65	24.24	25.84	12.40	19.37

Farm 1 - 2= two farmers field (Gadisa Beksisa and Sisay Belete), RI=Rhizobium inoculation, MV= maize varieties, W and J= Wenchi and Jibat maize variety, NS=Non-significant difference at 5 % probability level.

application of recommended nitrogen fertilizer was very crucial for sustainable maize production in the agroecology.

Interaction rhizobium inoculation with maize varieties and nitrogen fertilizer were significantly affected mean thousand seed weight, grain yield, dry biomass and harvest index maize (Tables 5, 9 and 11). Mean thousand seed weight was varied between two farms. Significantly, higher mean thousand seed weight 385 g was obtained from farm 1. Mean thousand seed weight of maize varieties were increased with increasing rate of nitrogen in the integration of the three rates. For both maize varieties, higher thousand weight was obtained with the application of recommended rates of nitrogen following faba bean precursor crop. This justifies the crucial role of nitrogen in increasing the seed size of maize varieties. Therefore, applying recommended rates of nitrogen was appropriate to harvest the required seed size of maize.

Interaction rhizobium inoculation with maize varieties and nitrogen fertilizer were significantly affected by mean grain yield, dry biomass and harvest index maize (Tables

9 and 11). Mean grain yield, dry biomass and harvest index of maize varieties were varied between farms indicating the difference between two farms with soil fertility status and other micro-environments due to light direction and rainfall distribution and amounts. Wenchi variety produce higher yield following faba bean precursor crop with and without rhizobium inoculation and with half recommended nitrogen fertilizer while Jibat with application of recommended nitrogen fertilizer. Jibat variety produced higher mean grain yield 7607 followed 6136 kg ha^{-1} by planting following faba bean precursor crop without rhizobium inoculation with application of recommended nitrogen fertilizer rate; and faba bean precursor crop with rhizobium inoculation and application of recommended nitrogen fertilizer rate (Table 8). Beslemes et al. (2013) found maize planted following faba bean green manure and maximum inorganic fertilization, exhibited higher seed production (12.24 Mg ha^{-1}) compared to the control unfertilized plots. Grain yield of maize significantly affected by interaction of preceding crop and N fertilizer application (El-Gizawy, 2009) and maize precedes faba bean and applied with 120 kg N ha^{-1} gave higher yield. KÖpke and Nemecek (2010) reported non-nitrogen precrop effects of Faba bean entails potential benefits via increased availability of soil phosphorus to the subsequent crops. Wenchi variety gave higher mean grain yield 6739 followed by 6617 kg ha^{-1} planted following faba bean precursor crop with rhizobium inoculation and applied with half recommended nitrogen fertilizer; and faba bean precursor crop with rhizobium inoculation and applied with recommended nitrogen fertilizer. This indicates nitrogen fertilizer response variation of the two varieties following faba bean precursor crop. In conclusion, knowing nitrogen fertilizer response maize varieties was very crucial for sustainable maize production in the region.

The mean dry biomass of maize varieties were 21667, and 30708 and 12625 kg ha^{-1} for farm 1 and farm 2, respectively (Table 11). Significantly, higher mean dry biomass was harvested from farm 1 as compared to farm 2 indicating the difference of the two farms with soil fertility status. Significantly, higher mean dry biomass (26117 and 25054 kg ha^{-1}) of Jibat variety was obtained from planting following faba bean precursor crop with rhizobium and with application of recommended nitrogen fertilizer; and faba bean precursor crop without rhizobium and with application of recommended nitrogen fertilizer. For Wenchi varieties higher mean dry biomass of 23054 and 22289 kg ha^{-1} were obtained by planting following faba bean precursor crop with rhizobium inoculation and with application of half recommended nitrogen fertilizer; and recommended nitrogen fertilizer. Beslemes et al. (2013) found maize planted following faba bean green manure and maximum inorganic fertilization, exhibited higher total biomass production (19.66 Mg ha-1), compared to the control unfertilized plots. Higher biomass production levels may result for both soil types mainly due to the increase in N-mineralization (base uptake) and the enhanced fertilizer recovery fraction (10-15 %) (Beslemes et al., 2013). Therefore, dry biomass production of two maize varieties was varied with faba bean precursor crop and nitrogen fertilizer application.

Mean harvest index of maize varieties was significantly varied between two farms. Mean harvest index of 28.85; 23.64 and 34.09% on farm 1 and farm 2, respectively, showing variations of the two fields. Wenchi variety gave higher harvest index as compared to Jibat variety following faba bean precursor crop with and without rhizobium and with application of nitrogen fertilizer. Mean harvest index of 37.46 and 34.67% were obtained from Wenchi variety planted following faba precursor crop without rhizobium and with application of full recommended; and half recommended nitrogen fertilizer. For Jibat variety, higher mean of 30.8 and 30.62% were harvested from planting following faba bean precursor crop without rhizobium inoculation and with application of full recommended nitrogen fertilizer and with rhizobium inoculation and with application of full recommended nitrogen fertilizer. Therefore, the harvest index of maize varieties were varied with soil fertility management applied.

Conclusion

The result soil analysis indicates that most of the nutrient concentrations were improved with planting of faba bean precursor crop without and with rhizobium inoculation. Harvest index of maize was significantly influenced by maize varieties, indicating variation the differences in two varieties. Application of nitrogen fertilizer significantly affected mean grain yield of maize varieties. Significantly, higher mean leaf area index and plant height of maize were obtained from maize planted with half recommended nitrogen fertilizer following faba bean precursor crop without and with rhizobium inoculation. Interaction of rhizobia inoculation with maize varieties and nitrogen fertilizer significantly affected mean leaf area, leaf area index, plant height thousand seed weight, grain yield, dry biomass and harvest index of maize varieties. Application of nitrogen fertilizer was significantly affected mean grain yield of maize varieties. Leaf area and leaf area index of maize varieties were significantly affected by interaction of faba bean precursor crop with maize varieties. Production of maize varieties following faba bean precursor crop without and with rhizobium inoculation and applying half recommended nitrogen fertilizer were recommended for sustainable maize production in high altitude areas of Toke Kutaye, western Ethiopia.

Acknowledgements

The authors thank Regional University Fund for Capacity

Building for funding the experiment. I am very grateful to Ambo Plant Protection Research center for providing me all necessary equipment's and logistics during the research work. All the technical and field assistants of Land and Water Resources Research Process are also acknowledged for unreserved effort during executing the experiment. Holleta and Debre Zeit Agricultural Research Center, Soil and Plant Analysis Laboratory are acknowledged for their provision of laboratory service for soil. I want to thank the farmers at Toke Kutaye for providing me their land for field research work.

REFERENCES

Badr SKA (1999). Effects of some preceding winter crops and application time of micro-nutrients on growth, yield and yield components of yellow maize in sandy soil. Minufiya J. of Agric. Res., 24(3): 895-909.

Birru A (1979): Agricultural Field Experiment Management Manual Part III. IAR (Institute of Agricultural Research). Addis Ababa, Ethiopia, pp. 35-42.

Beslemes DF, Tigka EL, Efthimiadis P, Danalatos NG (2013). Maize biomass production, N-use efficiency and potential bioethanol yield, under different cover cropping managements, nitrogen Influxes and soil types, in Mediterranean climate. J. of Agric. Sci., 5 (7):189-205.

Bray HR, Kurtz L (1945). Determination of organic and available forms of phosphorus in soils. Soil Sci., 9: 39-46.

Campbell CA, Zentner RP, Selles F, Bierderbeck VO, Leyshon AJ (1992). Comparative effects of grain lentil-wheat and monoculture wheat on crop production. N economy and N fertility in brown Chernozem. Can. J. Plant Sci., 72: 1091-1107.

Campbell CA, McConkey BG, Zentner RP, Selles F, Curtin D (1996). Long-term effects of tillage and crop rotations on soil organic C and total N in a clay soil in South-western Saskatchewan. Can. J. Soil Sci., 76: 395-401.

Chapman HD (1965). Cation exchange capacity in methods of soil analysis. Part 2. Agro. Mono., 9: 891-894.

Charpentier H, Doumbia S, Coulibaly Z, Zana O (1999). Stabilizing agriculture in northern and central Cote d'Ivoire: what are the new farming systems? Agric.-et-Devel. 21: 4-70.

Dewis J, Freitas F (1984). Physical and chemical methods of soil and water analysis. FAO Soil Bulletin No. 10. FAO, Rome. 275 p.

Dyke GV, Prew RD (1983). Beans in crop rotation. In: The Faba Bean (Vicia faba L.) Butter worths. (Edited by Hebblethwaite, P.D.). London, pp. 263–269.

El-Gizawy NKhB (2009). Effects of nitrogen rates and plant density on agronomic nitrogen use efficiency and maize yield following wheat and Faba bean. American-Eurasian J. of Agric. and Environ. Sci., 5(3): 378-386.

FAO (1990). Guideline for soil description. Rome 193 pp. Rome, Italy.

FAO (2006). Near East fertilizer-use manual. FAO/14152/F. Rome, Italy. 197 pp.

FAO. (2007). FAO World Reference Base for Soil Resources. World Soil Resources Report 103. FAO, Rome. 128 pp.

Giller KE, Wilson KF (1991). Nitrogen fixation in tropical cropping systems. CAB Inter. UK. 313 pp.

Giller KE, Amijee F, Brodrick SJ, Edje OT (1998). Environmental constraints to nodulation and nitrogen fixation of Phaseolus vulgaris L. in Tanzania. II. Response to N and P fertilizers and inoculation with Rhizobium. Afr. Crop Sci. J. 6:171-178.

Gungula DT, Togun AO, Kling JG (2005). The influence of N rates on maize leaf number and senescence in Nigeria. World J. of Agric. Sci. 1(1): 1-5.

Hauggaard-Nielsen H, Jørnsgaard B, Kinane J, Jensen ES (2008). Grain legume – cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renew. Agric. Food Syst. 23: 3-12.

Holford ICR, Crocker GJ (1997). A comparison of chickpeas and pasture legumes for sustaining yields and nitrogen status of subsequent wheat. Australian J. of Agric. Res. 48: 305-315.

Horneck DA, Sullivan DM, Owen JS, Hart JM (2011). Soil test interpretation guide. EM 1478. Corvallis, OR: Oregon State University Extension Service. 12p.

Jackson ML (1958). Soil Chemical Analysis. Prentice Hall, Inc., Engle Wood Cliffs. New Jersey. pp. 183-204.

Keeney DR, Nelson DW (1982). Nitrogen in organic forms. In: Methods of Soil Analysis. (Edited by Page, A.L., Miller, R.H. and Keeney. D.R.), Agronomy. Part II, No. 9, American Society of Agronomy. Madison, Wisconsin, USA, pp. 643–698.

KÖpke U, Nemecek T (2010). Ecological services of faba bean. Field Crops Res. 115: 217–233.

Kumar VDK, Dart PJ, Sastry PVS (1983). Residual effect of pigeon pea (Cajanus cajan) on yield and nitrogen response of maize. Exp. Agric., 19: 131-141.

Landon JR 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York 474 p.

Lo´ pez-Bellido L, Fuentes M, Castillo JE, Lo´ pez-Garrido FJ (1998). Effects of tillage, crop rotation and nitrogen fertilization on wheat-grain quality grown under rainfed Mediterranean conditions. Field Crops Res., 57: 265–276.

Loss SP, Siddique KHM, Tennant D (1997). Adaptation of faba bean (Vicia faba L.) to dryland Mediterranean-type environments. I. Seed yield and yield components. Field Crops Res., 54: 17–28.

Lupwayi NZ, Kennedy AC (2007). Grain legumes in Northern Great Plains: Impacts on selected biological soil processes. Agron. J., 99: 1700-1709.

Marx ES, Hart J, Stevens RG (1999). Soil test interpretation guide. EC 1478. Oregon State University Extension service. 8pp.

McLean EO (1965). Aluminum. In: Methods of soil analysis (Edited by Black, C.A.), American Society of Agronomy, Madison, Wisconsin, U.S.A. Agron. 9: 978-998.

Nelson LA, Voss RD, Pesek J (1985). Agronomic and statistical evaluation of fertilizer response 89 pp.

NMSA (2014). Meteorological data of Tokke Kutaye area for 2005-2013. NMSA, Addis Ababa, Ethiopia.

Nuruzzaman M, Lambers H, Bolland MDA, Veneklaas EJ (2005). Phosphorus benefits of different legume crops to subsequent wheat grown in different soils of Western Australia. Plant Soil. 271: 175–187.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA circ. 939: 1-19.

Oluoch- Kosura W (2013). Introduction. In: Africa agriculture status report: Focus on staple crops. Nairobi, Kenya. Alliance for Green Revolution in Africa (AGRA). pp. 13-16.

Pare T, Chalifour FP, Bourassa J, Antoun H (1993). The residual effects of faba bean and soybean for a 2nd and 3rd succeeding forage-corn production. Can. J. of Plant Sci., 73: 495-507.

Rochester IJ, Peoples MB, Hulugalle NR, Gault RR, Constable GA (2001). Using legumes to enhance nitrogen fertility and improve soil condition in cotton cropping systems. Field Crops Res., 70: 27–41.

Sanginga N (2003). Role of biological nitrogen fixation in legume based cropping systems; a case study of West Africa farming systems. Plant and Soil. 252:25–39.

Schwenke GD, Peoples MB, Turner GL, Herridge DF (1998). Does nitrogen fixation of commercial, dry land chickpea and faba bean crops in north- west New South Wales maintain or enhance soil nitrogen? Aust. J. of Exp. Agric., 38 (1): 61–70.

Shams SAA (2000). Effects of some preceding winter crops, nitrogen levels and zinc foliar application on grain yield of maize (Zea mays, L). Annu. of Agric. Sci., 38 (1): 47-63.

SAS (2010). SAS/STAT Software Syntax, Version 9.0. SAS Institute, Cary, NC. USA.

Steel RGD, Torrie JH (1980). Principles and procedures of statistics: a biometrical approach. 2nd Edition. McGraw-Hill. New York. 631pp.

Tolera A, Daba F, Friesen DK (2009). Effects of Crop rotation and N-P Fertilizer Rate on Grain Yield and related characteristics of Maize and Soil Fertility at Bako Western Oromia, Ethiopia. East Afr. J. of Sci. 3:

70-79.
Turpin JE, Herridge DF, Robertson MJ (2002). Nitrogen fixation and soil nitrate interactions in field-grown chickpea (Cicer arietinum) and faba bean (Vicia fabae). Aust. J. of Exp. Agric., 53: 599–608.
UNEP (2004). GEO (Global Environmental Outlook)-2003 Report. http://www.unep.org /geo/ yearbook /086.htm.
Vesterager Jens M, Nielsen Niels E, Høgh-Jensen H (2008). Effects of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea–maize systems. Nutr. Cycl. in Agroecos. 80:61–73.
Van Reeuwijk LP (1992). Procedures for soil analysis. 3rd edition. International Soil Reference and Information Center Wageningen (ISRIC). The Netherlands, Wageningen.
Walley FL, Clayton GW, Miller PR, Carr PM, Lafond GP (2007). Nitrogen Economy of Pulse Crop Production in the Northern Great Plains. Agron. J., 99:1710–1718.
Walkley A, Black CA (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chronic acid titration method. Soil Sci., 37: 29-38.
Wright AT (1990). Yield effect of pulses on subsequent cereal crops in the northern prairies. Can. J. of Plant Sci., 70: 1023-1032.
Wu TY, Schoenau JJ, Li FM, Qian PY, Malhi SS, Shi YC 2003. Effect of tillage and rotation on organic carbon forms in chernozemic soils in Saskatchewan. J. Plant Nutr. Soil Sci., 166: 385 – 393.