EFFECTS OF LEGUME BREAK CROPS ON YIELD, NITROGEN USE EFFICIENCY AND ECONOMY OF MAIZE PRODUCTION IN WESTERN OROMIA, ETHIOPIA
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Tolera Abera
Natural Resources Management Research Process, Ambo Agricultural Research Center, Ethiopian Institute of Agricultural Research, Ambo, Oromia, Ethiopia,
e-mail: thawwii2014@gmail.com; thawwii@yahoo.com

ABSTRACT

Prolonged monocropping of maize lacking appropriate soil fertility management is affecting soil fertility and maize production in Western Oromia. The use of legume break crops improved performance of subsequent maize. The biological N_2-fixation of legumes as precursor crops reduced the amount of nitrogen fertilizer applied to maize. Higher mean grain yield of maize was obtained following faba bean without and with rhizobia inoculation than maize after maize. The total nitrogen uptake of different maize varieties was improved following leguminous break crops with application of lower amounts of nitrogen fertilizer. Higher agronomic nitrogen efficiency, fertilizer N recovery efficiency and nitrogen use efficiency of maize were obtained from 55 kg N ha^{-1} application as compared to 110 kg N ha^{-1} following legume break crops. Production of highland maize varieties following faba bean and soybean with half recommended rate of 55 kg N ha^{-1} improved mean maize grain yield has been recommended for maize production in western Ethiopia. Therefore, fertilizer management practices following legumes break that increase nitrogen use efficiency and improve yield of cereals will likely be more effective and desirable options for maize production. Further research can be undertaken on the interaction of nitrogen rates and legume break crops to determine economically optimum nitrogen rates for maize after legumes break crops and nitrogen use efficiency and economy of production in Ethiopia.

Keywords: break crops, legumes, nitrogen, maize

INTRODUCTION

The provision of food, fiber and fuel, climate regulation and carbon sequestration, will increasingly depend on the availability of healthy and sustainably managed soils (FAO, 2020). However, soil fertility depletion is considered as the major threats to food security in Ethiopia. Conventional agriculture (continuous cropping with low inputs) has certain limitations in terms of maintaining long-term soil fertility (Charpentier et al., 1999). Wu et al. (2003) reported that longer cultivation has further depleted the soil organic-matter content and fertility of these soils. Wakene (2001) reported that continuous monocropping with heavy applications of N and P fertilizers and intensive mechanized tillage practice lead to increased soil acidity, degradation of organic carbon and leaching of the exchangeable bases. Hence, decreasing productivity can be alleviated by different methods such as use of inorganic nitrogen and use of legumes in a cropping system. Well managed fertile soils are the foundation for sustainable food production and many essential ecosystem services.

Legumes contribute to the maintenance and restoration of soil fertility by fixing N_2 from the atmosphere (Giller and Wilson, 1991). Azam and Farooq (2003) reported symbiotic nitrogen fixation by legumes is the major natural process of adding nitrogen into the biosphere, amounting to about 35 million tons globally annually. Optimizing this symbiosis can increase crop yields and enhance soil fertility, whilst reducing the negative monetary costs and environmental impacts associated with nitrogen fertilizer use (Canfield et al., 2010; Hirel et al., 2007; and Peoples et al., 2009).

Quantities of N fixed in faba bean vary greatly but estimates of rates of fixation vary from 40 (Duc et al., 1988); 93% (Brunner and Zapata, 1984) to 120 kg N ha^{-1} (Danso, 1992) of crop N, and from 16 to 300 kg aboveground N per ha per crop. Khan et al. (2002) harvested plant parts and found that root-zone soil represented 39% of total plant N for faba bean. The soil N contents were improved 10.6 times more than the original soil N content (0.014%) from the plots where faba beans were grown (Fassile, 2010). Significant yield increases of faba bean from biological N_2-fixation of 82 kg N ha^{-1} of 1.4 t ha^{-1} grain yields were obtained (Beck and Duc, 1991); representing 35 to 69% increase due to the inoculation (Khosravi et al., 2001).

The input of fixed N from grain legumes may be a significant contributing factor in relation to sustaining productivity in smallholder systems (Sanginga, 2003). Lassaletta et al. (2014) suggested that an increase in the contribution of symbiotic N fixation would result in increasing NUE. Lo´pez-Bellido et al. (2006) found that nitrogen derived from the atmosphere (Ndfa) percentages ranged between 70 and 96%, and N_2-fixed between 39 and 144 kg N ha^{-1} in faba bean. The N agronomic efficiency and N fertilizer recovery efficiency of maize following grain legumes were on average 14 and 34% greater than of maize following maize and 12 and 20% greater than of maize following fallow, respectively (Yusuf et al., 2009). Therefore, estimating the biological nitrogen fixation by faba bean with and without rhizobia inoculation and determining its effects of nitrogen requirement of subsequent maize are potential for increased maize production. The objective this study was to determine the effects of faba bean precursor crop biomass incorporation on yields and nitrogen use efficiency of subsequent maize varieties in Tokke 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 Ethiopia. The area in Toke Kutaye lies between 8°9'8" and 8^{0}71˙21"N and 37°72' and 37^{0}42' E and located at the 2,262 and 2,322 meter above sea level, with mean annual rainfall of 1,045 mm (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 experiment was conducted in 2013 and 2014 cropping season. The faba bean (variety Moti) in the highland were planted with and without rhizobia inoculation in the preceding cropping season as precursor crop. The rhizobia strain (FB-1035 for faba bean was used for the inoculation. Both precursor crops were planted, managed, and harvested following recommended agronomic packages and residues was incorporated in the field. In the second year (2014 cropping season), two maize hybrid varieties (Wenchi and Jibat) were sown with three levels of nitrogen on the two fields. Twelve treatment combinations were imposed with the main crop (maize). The maize hybrid was planted with three levels of nitrogen fertilizers onto plots of faba bean precursor crop biomass with and without rhizobia inoculation. The experiment was laid out in 2 x 2 x 3 factorial arrangement in randomized complete block design in three replications in 2014. The two types of faba bean field (with and without rhizobia inoculation) were used as factor A, the two maize varieties (Wenchi and Jibat) were used as factor B while the three levels of nitrogen (0, 55, 110 kg N ha^{-1}) were used as factor C, resulting in 12 treatment combinations.

The grain yield of maize varieties was recorded at physiological maturity and was adjusted to 12.5% moisture level (Birru, 1979; Nelson et al., 1985). The maize tissue samples were taken from the stalk and from grain at harvesting. The maize tissues and grains were subjected to wet digestion (Jones and Case, 1990). The N content of the plant tissue was determined by a Kjeldahl procedure according to Murphy and Riley (1962). The total N uptake was obtained by dividing the N concentration in the tissue to total dry biomass weight (kg ha^{-1}) of maize, whereas N agronomic efficiency (NAE) was obtained by dividing the grain yield to the applied N (Wu et al, 2011; Cleemput et al. 2008). The N use efficiency (UEN) is the total amount of N absorbed (including that present in the roots, often disregarded) per kg of applied N. The nitrogen physiological efficiency was calculated as total dry matter or grain yield produced per unit of N absorbed. N utilization efficiency was calculated as (Haegele, 2012). Apparent fertilizer N use (recovery) efficiency (ANRE) (equation 4) is the amount of fertilizer N taken up by the plant per kg of N applied as fertilizer, which was calculated as described by Azizian and Sepaskhah (2014), Cleemput et al. (2008), Craswell and Godwin (1984). Then, N harvest index (NHI) at maturity was calculated (Jones and Case, 1990) and an accumulation (kg N ha^{-1}) in the shoots or grains was calculated (Seleiman et al., 2013; Xu et al. 2006). Agronomic and nitrogen use efficiencies data analysed using statistical packages and procedures of Statistical Analysis System Computer Software. The mean separation was done using least significance difference procedure at 5 % probability level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The mean grain yields were significantly ($P<0.05$) higher for maize planted following faba bean precursor crop with the application of 55 and 110 kg N ha^{-1}. Significantly ($P<0.05$) higher (7718 and 5132 kg ha^{-1}) mean grain yield maize was obtained from application half recommended nitrogen fertilizer following faba bean precursor crop in Farm 1. and Farm 2 (Table 1). This indicates variation in fertility status of different farm fields.

The mean total nitrogen uptake of maize varieties was significantly ($P<0.05$) affected by application nitrogen fertilizer rates (Table 1). Higher total nitrogen uptake of maize was obtained from application both 55 and 110 kg N ha^{-1} in Farm 1 and Farm 2 as compared to control. Similarly, Beslemes et al. (2013) reported significant differences ($P<0.05$ and $P<0.01$) on total N uptake of maize with increased N fertilization levels. Maize that received 120 kg N ha^{-1} in addition to faba bean biomass also had higher grain N uptake (El-Gizawy, 2009). Increased N uptake with application of nitrogen as compared to without fertilizer indicates better improvement soil N status (and organic matter) following precursor crop biomass, leading to enhanced nitrogen uptake by maize.

The nitrogen agronomic efficiency of the two maize varieties varied among farms, maize varieties, and precursor crop biomass without/with rhizobia (Table 1). Significantly and non-significantly higher ($P<0.05$) nitrogen agronomic efficiency of maize was observed from maize planted following faba bean precursor crop biomass without rhizobia inoculation as compared to with inoculation in Farm 1 and Farm 2. This indicates faba bean precursor crop without rhizobia gave higher biological N_2-fixation due to effective native rhizobia.

Maize varieties showed significant ($P<0.05$) difference in nitrogen agronomic efficiency following faba bean precursor biomass in Farm 1 and 2, with significantly higher nitrogen agronomic efficiency achieved from Jibat maize variety as compared to Wenchi (Table 1). The result obtained match with better grain yield of Jibat maize variety from Farm 1 and 2 Table 2. Therefore, use of Jibat maize variety should be recommended for producers in the area.

Table 1. Effects of faba bean biomass, maize varieties and nitrogen rates on grain yield, Total nitrogen uptake, nitrogen agronomic efficiency and N use efficiency of subsequent maize in Toke Kutaye, western Ethiopia in 2014 cropping season.

Treatment	Farm 1				Farm 2			
	Grain yield, kg ha^{-1}	Total nitrogen uptake, kg ha^{-1}	Agronomic efficiency, Kg grain kg N applied^{-1}	Nitrogen use efficiency, kg N uptake kg N applied^{-1}	Grain yield, kg ha^{-1}	Total nitrogen uptake, kg ha^{-1}	Agronomic efficiency, kg grain kg N applied^{-1}	Nitrogen use efficiency, kg N uptake kg N applied^{-1}
Biomass of faba bean no inoculated with rhizobia	6988	698	43a	2.62b	4585	436	16.33	2.37a
Biomass of inoculated faba bean	7523	824	27b	5.32a	4272	408	14.94	1.47b
LSD (5%)	NS	NS	3.73	0.2864	NS	NS	NS	0.4922
Maize Varieties								
Wenchi	7351	698	30.81b	3.74b	4607	414	15.03a	2.32a
Jibat	7161	824	39.63a	4.20a	4249	429	12.79b	1.51b
LSD (5%)	NS	NS	3.73	0.2864	NS	NS	1.948	0.4922
Mineral N rates (kg ha^{-1})								
0	5934b	655b			3804b	329c		
55	7718a	815a	46.07a	4.94a	4349b	438b	16.745	3.09a
110	8115a	813a	21.32b	2.24b	5132a	498a	10.58	2.28b
LSD (5%)	1393	157.27	15.216	0.71	558	41.167	3.32	0.052
CV (%)	22.99	24.41	17.36	21.02	15.10	11.53	12.94	14.07

NS=non-significant difference, Numbers followed by same letter in the same column are not significantly different at 5% probability level.

The application of nitrogen fertilizer rates significantly ($P<0.05$) affected nitrogen agronomic efficiency of maize varieties following faba bean precursor crop biomass in Farm 1and 2 (Table 1). In both farms higher mean nitrogen agronomic efficiency of (46.07 and 16.75 kg grain kg N applied^{-1}) were obtained with application 55 kg N ha^{-1} as compared to 110 kg N ha^{-1}. Similarly, Amanullah and Alkas (2009) reported NAE was 28 kg (kg N)$^{-1}$ at an application rate of 60 kg N ha^{-1} but decreased to 23 and 19 kg (kg N)$^{-1}$ at application rates of 120 and 180 kg N ha^{-1}, respectively.

The nitrogen use efficiency of maize varieties was higher ($P<0.05$) following faba bean precursor crop with rhizobia inoculation as compared without rhizobia in Farm 1 but the opposite was observed in Farm 2. This indicates that Farm 1 and Farm 2 had differences in soil N fertility status (Table 1).

Maize varieties showed significant ($P<0.05$) difference in nitrogen use efficiency in both farms following faba bean precursor crop. Wenchi had higher mean nitrogen use efficiency following faba bean precursor crop with and without rhizobia inoculation in Farm 1 and 2 which entails matching of higher grain yield of Wenchi maize variety as indicated in Table 1. Even though not significantly different in grain yield, the result obtained matched with higher nitrogen use efficiency of maize varieties in both farms.

The application of nitrogen fertilizer significantly ($P<0.05$) affected nitrogen use efficiency of the maize varieties. Significantly higher nitrogen use efficiency was gained from maize varieties planted with 55 kg N ha^{-1} (as compared to 110 kg N ha^{-1}) following incorporation of faba bean precursor crop biomass in Farm 1 and farm 2, respectively. This implies that both maize varieties (Wenchi and Jibat) were efficient in using N under the lower mineral nitrogen input system, which could be affordable by resource poor smallholder farmers in the area. Goodroad and Jellum (1988) found higher nitrogen use efficiency was obtained when nutrient concentration was near the critical level, and this was true in the present situation whereby the total N levels in the present study sites were rated as being low to medium. The result agrees with results of Ortiz-Monasterio et al. (1997); Woldeyesus et al. (2004) who reported that N uptake efficiency was higher at lower rates of N application, but drastically decreased with further increases in the rate of the N.

Nitrogen physiological efficiency of subsequent maize in Toke Kutaye

Nitrogen physiological efficiency of maize varieties were significantly (P<0.05) affected faba bean biomass incorporation, maize varieties, and nitrogen rates application in Farm 1 and 2 (Table 2). Higher nitrogen physiological efficiency of 30.19 and 17.49 kg grain kg N uptake^{-1} were achieved from of maize planted following incorporation of faba bean precursor crop without prior rhizobia inoculation in Farm 1 and Farm 2 (Table 2). This indicates the presence competitive indigenous rhizobia strains in the soil. The result did not match with grain yield variation following faba bean precursor crop biomass incorporation in Table 2.

The maize varieties used showed significant (P<0.05) difference in nitrogen physiological efficiency (Table 2) The mean nitrogen physiological efficiency of 21.89 kg grain kg N uptake^{-1} was attained from Jibat maize variety in Farm 1 following faba bean precursor crop. Wenchi maize variety had higher maize nitrogen physiological efficiency of 17.23 kg grain kg N uptake^{-1} in Farm 2 following faba bean precursor crops. Likewise, Eivazi and Habibi (2013) found variation in nitrogen physiological efficiency between single cross maize varieties, which is true for three-way crosses of Wenchi, and Jibat hybrid maize varieties currently used for the study.

The nitrogen physiological efficiency of both maize varieties significantly (P<0.05) affected by nitrogen fertilizer rates in Farm 1 and 2 (Table 2). Significantly higher nitrogen physiological efficiency at the higher nitrogen fertilizer rate (following faba bean precursor crop). Similarly, Beslemes *et al*. (2013) found significant differences for faba bean green manure management and N fertilization on the N physiological efficiency of maize. The N physiological efficiency of maize following legumes increased significantly with increasing nitrogen rates **(**Yusuf, *et al*., 2009)**.** Higher mean nitrogen physiological efficiency attained with application 110 kg N ha^{-1} as compared 55 kg N ha^{-1} implies increasing N uptake as N supply increases and it suggests that higher grain yield could be achieved at higher N rate (Yusuf, *et al*., 2009). In contrary, Barbieri *et al*. (2008) reported that physiological efficiency of maize decreased with increasing rates of nitrogen fertilizer application. Further research will be needed to improve the nitrogen physiological efficiency by matching application rate and timing with plant demands.

Fertilize N (recovery) use efficiency of subsequent maize in Toke Kutaye

The fertilizer N (recovery) use efficiency of maize varieties were significantly (P<0.05) affected faba bean biomass incorporation, maize varieties, and nitrogen rates application in Farm 1 and 2 (Table 2). Higher fertilizer N (recovery) use efficiency of 532 and 237% maize varieties were obtained from Farm 1 and Farm 2 following incorporation faba bean precursor crop biomass with rhizobia inoculation and without, respectively (Table 2). Miller and Heitchel (1995) reported that N recovery following green manure crops might vary due to the amount of N fixed, mass of plant material incorporated, rate of decomposition and immobilization of legume N in the soil. N fertilizer recovery efficiency (REN) was significantly after legumes than after natural fallow or maize (Yusuf *et al*., 2009) to the tune of 34 and 20% greater than that of maize following maize and fallow, respectively (Yusuf *et al*., 2009). The N recovery fraction was enhanced by 10-15% after faba bean cover cropping, for sandy and clayey soil (Beslemes *et al*., 2013). Ladd (1981) showed 23 and 4% recovery of N in wheat following incorporation of medic residues the first and second year, respectively. Maize plants were observed to recover only 17-25% of the N from alfalfa residues (Harris and Hesterman 1987) implying the need for supplemental mineral N. In contrary, Carsky *et al*. (1999) reported lower REN values in maize following soybean genotype than maize following natural fallow.

Cassman *et al*. (2002) stated that when soil-N content is increasing, the amount of sequestered N contributes to higher nitrogen use efficiency (NUE) of the cropping system, and the amount of sequestered N derived from applied N contributes to higher N fertilizer recovery efficiency.

Table 2. Effects of faba bean biomass, maize varieties and nitrogen rates on Nitrogen physiological efficiency, Fertilize N (recovery) use efficiency, shoot and grain N accumulation, and N harvest index of subsequent maize in Toke Kutaye, western Ethiopia in 2014 cropping season.

Treatment	Farm 1				
	Nitrogen physiological efficiency, kg grain kg N uptake^{-1}	Fertilize N (recovery) use efficiency, %	Shoot N accumulation, kg ha^{-1}	Grain N accumulation, kg ha^{-1}	N Harvesting index, %
Biomass of faba bean no inoculated with rhizobia	30.19b	262b	6.31b	8.86	0.59
Biomass of inoculated faba bean	9.8b	532a	6.64a	9.67	0.59
LSD (5%)	3.016	40.45	0.003	NS	NS
Maize Varieties					
Wenchi	14.15b	374b	7.32a	9.02	0.55b
Jibat	21.89a	420a	5.63b	9.52	0.63a
LSD (5%)	3.016	40.45	0.003	NS	0.044
Mineral N rates, kg ha^{1}					
0			5.06b	7.00b	0.58
55	12.89b	494a	6.42ab	9.82a	0.62
110	22.84a	339b	7.93a	10.98a	0.57
LSD (5%)	8.45	145	1.639	1.6954	NS
CV (%)	22.36	22.14	18.92	21.61	14.67
Treatment	**Farm 2**				
	Nitrogen physiological efficiency, kg grain kg N uptake^{-1}	Fertilize N (recovery) use efficiency, %	Shoot N accumulation, kg ha^{-1}	Grain N accumulation, kg ha^{-1}	N Harvesting index, %
Biomass of faba bean no inoculated with rhizobia	17.49a	237a	5.20a	6.03	0.53
Biomass of inoculated faba bean	12.86b	147b	5.05b	5.98	0.54
LSD (5%)	3.3737	14.58	0.0032	NS	NS
Maize Varieties					
Wenchi	17.23a	231a	5.59a	5.90	0.52b
Jibat	13.12b	152b	4.66b	6.11	0.56a
LSD (5%)	3.3737	14.58	0.0032	NS	0.0225
Mineral N rates, kg ha^{1}					
0			4.22b	4.76c	0.53b
55	10.20b	229a	5.75a	5.95b	0.52b
110	14.64a	154b	5.43a	7.30a	0.58a
LSD (5%)	3.47	47.16	0.4546	0.6243	0.052
CV (%)	24.47	15.91	7.95	12.28	8.18

NS=non-significant difference, Numbers followed by same letter in the same column are not significantly different at 5% probability level.

The maize varieties showed significant ($P<0.05$) difference with fertilizer N (recovery) use efficiency in both farms. Jibat maize variety had higher fertilizer N (recovery) use efficiency in Farm 1 but Wenchi maize variety had higher efficiency in Farm 2 following faba bean precursor crop biomass. This implies both maize varieties had different fertilizer N (recovery) use efficiency in different locations. The variation in fertilizer N (recovery) use efficiency of maize varieties was also reported Eivazi and Habibi (2013).

The nitrogen fertilizer rate at 55 kg N ha^{-1} significantly ($P<0.05$) higher on fertilizer N (recovery) use efficiency of maize varieties in both farms (Table 2). The N recovery gradually decreased with increase N as was also observed by others (El-Gizawy, 2005; 2009; Berenger *et al*. 2009). This implies the response to fertilization was very poor, but analysis of grain yield and N uptake showed significant differences between all fertilizer rates (Yusuf *et al*., 2009). Therefore, the wide adoption of maize varieties following faba bean precursor crop is desirable for increased maize yields under smallholder farms with application half recommended N fertilizer rate in the region.

Shoot and grain N accumulation, and N harvest index of subsequent maize in Toke Kutaye

Shoot N accumulation of maize varieties was significantly ($P<0.05$) affected using faba bean precursor crop with and without rhizobia inoculation in both farms (Table 2). This might be due to differences the fertility status and historic management practices applied to the two farms.

The maize varieties showed significant ($P<0.05$) difference in mean shoot N accumulation in Farm 1 and Farm 2 following incorporation of faba bean precursor crop. Wenchi variety gave higher shoot N accumulation as compared to Jibat maize variety in both farms had been planted with faba bean precursor crop. The shoot N content of maize was varied between hybrid maize varieties (Uribelarrea *et al*., 2009).

Application of nitrogen fertilizer rates significantly ($P<0.05$) affected shoot N accumulation of maize varieties (Table 2). Significantly higher shoot N accumulation of maize varieties were obtained with higher N fertilizer rates application. Similarly, Moser (2004) found that shoot N concentration increased as the rate of N application increased in tropical maize varieties. Increase of nitrogen rates showed significant difference for shoot N accumulation of maize varieties (Uribelarrea *et al*. (2009). Similarly, nitrogen fertilizer application rates significantly influenced shoot N yield and increased with increases in N rate (Kidist, 2013; Muurinen, 2007; Woldeyesus *et al*., 2004).

Grain N accumulation of maize varieties was significantly ($P<0.05$) affected by N fertilizer application but non-significant the use of faba bean precursor crop with and without rhizobia inoculation in both farms and maize varieties (Table 2). The mean grain N accumulation of maize varieties increased significantly ($P<0.05$) as the rates of nitrogen fertilizer increased from 0 to 110 kg N ha^{1}, indicating direct influence of nitrogen application on seed development due to its role in amino acid and nucleic acid synthesis, both of which contain nitrogen. Maize planted after faba bean that received 120 kg N ha^{-1} also gave higher grain N uptake (El-Gizawy, 2009). Likewise, variation due to nitrogen application rate was observed for grain N concentration (Uribelarrea *et al*. (2009). Therefore, application of recommended nitrogen fertilizer could increase grain N accumulation of maize varieties.

N harvest index of maize varieties was significantly ($P<0.05$) affected by maize varieties and application N fertilizer rates (Table 2). The maize varieties used significantly ($P<0.05$) varied with N harvest index of maize following faba bean precursor crop in both farms (Table 2). There was variation in N harvest index between farms, maize varieties, precursor crop and application of nitrogen rates. This implies that different sites will vary in this characteristic. The application of nitrogen fertilizer rates following faba bean precursor crop significantly

($P<0.05$) increased N harvest index of both maize varieties in Farm 2 but non-significant ($P<0.05$) for Farm 1 (Table 2). Kidist (2013) also found that nitrogen fertilizer application rates significantly influenced nitrogen harvest index of maize.

CONCLUSION

Higher agronomic efficiency, fertilizer N (recovery) use efficiency and nitrogen use efficiency of maize were obtained from 55 kg N ha^{-1} application as compared to 110 kg N ha^{-1}, which matched with higher grain yields of maize. Improved yields of maize following faba bean precursor crop without and with rhizobia inoculation and applying half recommended rate of nitrogen fertilizer (55 kg N ha^{-1}) in high altitude areas of western Ethiopia. Therefore, fertilizer management practices following legumes precursor crop biomass incorporation that increase nitrogen use efficiency and improve yield of maize will likely be more effective and desirable options for the area. The results from this series of studies suggest possibilities for further research work on optimum nitrogen rate, interaction of faba bean precursor crop biomass incorporation with nitrogen rates in the production of maize in other areas of western Ethiopia.

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