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Yield Response of Common Bean to Phosphorus, Lime and Compost Application at Areka, Southern Ethiopia

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Abstract

Field experiments were conducted to investigate the response of common bean to the application of phosphorus, lime and compost under field condition at Areka during Belg and Meher seasons in 2013. The treatments consisted of three rates of compost (0, 5 and 10 tonnes ha^{-1}), three rates of lime (0, 0.64 and 1.28 tonne ha^{-1}) and three rates of phosphorus (0, 23 and 46 kg P_2O_5 ha^{-1}). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times. The results revealed that main effects of compost, lime, and phosphorus were significant for number of pods plant^{-1} and number of seeds pod^{-1}. Grain yield responded to two-factor interactions effect of lime × phosphorus in both seasons and compost × phosphorus, compost × lime only in Belg and lime × phosphorus in Meher season. Hence, in Belg the maximum (2834.9 kg ha^{-1}) grain yield was obtained as a result of combined application of lime and phosphorus at rates of 1.28 tonne and 46 kg P_2O_5 ha^{-1}, respectively. Similarly, in Meher the highest grain yield (2418.1 kg ha^{-1}) was obtained due to application of compost and lime at rates of 10 and 1.28 tonnes ha^{-1}, respectively. However, application of phosphorus alone at rate of 23 kg P_2O_5 ha^{-1} was found economically viable. In conclusion, considering immediate economic benefit application of phosphorus at the aforementioned rate is vital, whereas for long-term sustainable improvement of the soil and productivity combined application of the technologies is recommended.

Keywords: Compost, cost-benefit analysis, grain yield, lime, phosphorus

Introduction

Soil degradation and drought are serious threats to agriculture, causing frequent crop failure and hunger (Buruchara *et al.,* 2011). Declining per capita crop production on smallholder farms in sub-Saharan Africa is also associated with soil fertility degradation (Mugwe *et al.,* 2007). Likewise, in the Ethiopian highlands, soil degradation, which is mainly due to intensive cultivation, nutrient depletion, and soil erosion, is a serious problem resulting in yield decline (Balesh, 2005). Further, farmers have been applying low rates of nitrogen and phosphorus fertilizers than would be sufficient for high yields of crops (Kefyalew, 2011), which aggravates the problem of low soil fertility. Continued use of nitogen and phosphate fertilizers alone has not only resulting in the mining of other nutrients but also increased the acidity of the soils (Eyasu, 2002; 2013).

Soil acidity is one form of soil degradation problem in the country in general and in the Southern region in particular (Schlede, 1989; Wasie and

Shiferaw, 2009). In areas receiving high rainfall, soil acidity is a natural process, which is most cases is accelerated by activities of plants, animals and humans (Bolan *et al.,* 2003). The situation is rather serious in Nitisol and Luvisol areas of the southern and south-western highlands of Ethiopia (Eyasu, 2013). Low nutrient availability mainly phosphorus and other essential macro and micronutrients (Crowford *et al.,* 2008; Eyasu, 2013) and toxicities of Al and Mn (Kochian *et al.,* 2004) are the major problems attributed to soil acidity. The solubility of soil P-containing compounds is greatest at pH ranging from 6.2 to 6.5 and reduced as soil clay content increases (Alley and Vanlauwe, 2009).

According to Lunze *et al.* (2002) study in Central and Eastern Africa, common bean production is constrained by low availability of nutrients and soil acidity. In line with this, in Ethiopia common bean production is constrained by poor soil fertility related to soil acidity (Mesfin, 2007), which in turn results in poor nodulation because of the low contents of available phosphorus (Kouas *et al.,* 2005). The low yield of common bean crop under smallholder farming in Ethiopia has been reported (CSA, 2013) and attributed to soil fertility problems (Katungi *et al.,* 2010).

Mugwe *et al.* (2007) suggested the need of appropriate soil fertility regimes for improved crop productivity. Several research results (Mupangwa and Tagwira, 2005; Osundwa *et al.,* 2013) revealed a significant increase in yield in response to single application of lime) and P fertilizer (Manoj-Kumar et al., 2012) or the combined application of lime with inorganic fertilizers (Abay, 2011; Abreha *et al.,* 2013). Further, Gruhn *et al.* (1995) observed and reported that the application of inorganic fertilizers alone is inadequate to keep soil nutrient loss by different means in balance and do not maintain soil structure.

Significant increases in yield had been reported as a result of the application of organic fertilizer alone or to integrated application of both organic and inorganic fertilizer (Abunvewa *et al.,* 2007; Laxminarayana *et al.,* 2011). Hence, integrated plant nutrient management, which is a holistic approach to optimizing plant nutrient supply, is required (Laxminarayana *et al.,* 2011). Fageria (2008) also suggested the application of balanced nutrition and adequate rate of lime on highly weathered tropical acid soils to maximize the profit of bean growing farmers.

In Southern Ethiopia, striking results have been obtained on acid soils by combined application of lime and inorganic fertilizers (Wassie and Shiferaw, 2009; Abay, 2011). Wasie and Shiferaw (2009) reported significantly highest potato tuber yields in response to application of lime and inorganic fertilizer on acid soils of Chencha while Abay (2011) had reported a significantly higher grain yield of maize over control due to the combined application of lime with nitrogen at Areka. In view of these, application of inorganic and organic nutrient sources is imperative for maximizing productivity of common bean in Ethiopia in general and in the study area in particular. However, there is scarce information at Areka regarding the effects of combined application of lime, organic, and inorganic fertilizers on common bean productivity. Therefore, this study was set out to explore the response of common bean to combined application of P, lime, and compost under field conditions in Areka, Southern Ethiopia.

Materials and Methods

Description of the study area

Field experiments were conducted in 2013 at Areka Agricultural Research Centre situated in the Southern Nation, Nationalities, and People's Regional State between 7^{0}3′25′ latitude to the North and from 37^{0}40′52′′ longitude to the East. The area is found at an altitude of 2,230 meters above sea level and the soil which is very deep and clayey in texture has been described as haplic alfisol (Abayneh *et al.,* 2003). The area has two rainy seasons; the *Belg* (April to mid-July) and *Meher* season (late July to October). In the cropping season, the rainfall commenced in January and began to increase sharply in March and again started to decline in May, increasing again until it reached a peak in August. In 2013 cropping season, the total annual rainfall received at Areka was 1586 mm, while the mean monthly rainfall received was 132.2 mm. Similarly, the average monthly temperature ranged from 17 to 18^{0}C during the *belg* season. Similarly, during the *meher* season, the average monthly temperature ranged from 17 to 18^0 C (AARC, 2013).

The liming materials used for this experiment were. The Purity of lime ($CaCO_3$) used for the field experiment was 89%, while the purity of CaO used for the incubation experiment was 98%.

Determination of lime requirement

For determination of lime requirement of soils of Areka, lime (CaO) was applied at the rates of 0, 0.56, 1.12, 1.68, 2.24 and 3.36 g kg^{-1} to soil samples each weighing 1 kg and were uniformly mixed. Then, the soil samples were added in triplicates into a pot with a capacity of containing 1 kg soil. Water was added into the samples approximately to field capacity. The soil in the pot were thoroughly mixed and incubated under room temperature for a period of two weeks. Then, the pH in water for individual pots was determined. The relationships between the amounts of CaO applied and the pH values obtained were plotted and the rate of CaO sufficient to raise the pH of the soil to desired pH was determined. The $CaCO_3$ equivalent of CaO was used for subsequent liming experiment.

Treatments and experimental design

The treatments consisted of three phosphorus rates (0, 23 and 46 kg P_2O_5 ha^{-1}), three lime rates (0, 0.64 and 1.28 tonnes ha^{-1}) and three compost rates (0, 5 and 10 tonnes ha^{-1}) combined factorialy and laid out in a randomized complete design with three replications. Each treatment was assigned randomly to plots. The common bean cultivar (Dinkinesh) used was obtained from Melkasa Agricultural Research Center, Ethiopia, and triple super phosphate (TSP) [Ca $(H_2PO_4)_2$] (21% P), Urea [CO $(NH_2)_2$] (46% N), and CaO/$CaCO_3$ were used as the sources of P, N, and lime respectively. The compost was prepared from locally available materials (teff and wheat straw, green leafy materials of easily decomposable tree species such as *erythrina sp.* and *Cordia abysinica)* combined with care produce a 30:1 C: N ratio following the procedure of FAO (2003).

The experimental plot had a 2.8 m width and a 3 m length. There were 7 rows per plot at the spacing of 40 cm between plants. Plots within block are 1m apart and blocks are 2m apart. The middle rows were used for yield (agronomic) data collection. The two outside rows were left as border rows while the immediate inner rows on both sides were used for destructive sampling.

Experimental procedure

Land preparation of the experimental field was done using a tractor to plough three times prior to planting during the Belg and Meher seasons. In each season, the experiment was done at different fields. The experimental field was ed by Similarly, other crop management practices such as pest and disease control were done following the standard agronomic practice for the crop. Lime was applied (broadcasted) two months prior to planting of the crop. Compost was applied in broadcast one month prior to planting in rows. The phosphorus fertilizer was band applied at planting and nitrogen was applied at the rate of 18 kg N ha^{-1} at the active stage of vegetative growth before flowering (MoRAD, 2008).

Soil and compost analysis

Available P was determined by Bray I method using ammonium fluoride as an extractant and measuring the concentration of the nutrient at 880 nm (Bray and Kurtz, 1945). Soil organic carbon was determined by the Walkley-Black wet digestion method (Walkley and Black, 1934). Total N was determined by the wet oxidation procedure of the Kjeldhal method (Bremner, 1995). Cation exchange capacity was determined with ammonium acetate saturated samples using sodium (Na) from percolating NaCl solution to replace the ammonium ions. The displaced ammonium was measured using the modified Kjeldahl procedure and was reported as CEC (Chapman, 1965). Soil pH was determined potentometrically in supernatant suspension of 1:2.5 soils: water ratio using a combined glass electrode pH meter (Chopra and Kanwar, 1976).

Exchangeable bases (Ca, Mg, K and Na) in the soil were estimated by the ammonium acetate (1M NHOAc at pH 7) extraction method as described by Rowell (1994). Compost was also analyzed for total N, available P, Ca, Mg and K after wet digestion of the samples.

Data collection

Data collected includes number of pods per plant, and number of seeds per pod from 5 randomly selected plants in the net plot area at harvest. The aboveground biomass and grain yield per hectare and harvest index (HI) were also determined from harvested plants in the net plot area at harvest. Grain yield was determined after adjusting the moisture content to 10%.

Statistical analysis

The two season data collected were tested for homogeneity of variance using F-test (Gomez and Gomez, 1984). The F-test test indicated that the treatment means were significantly different for the parameters between the two seasons. Accordingly, separate analysis was done. All data were subjected to analysis of variance using SAS version 8, Statistical software. Significant means were separated using LSD test.

Economic analysis

The partial budget analysis to evaluate the economic viability of the fertilizer and manure rates was performed considering only costs that vary following the procedures as described by CIMMYT (1988).

Results and Discussion

Soil physico-chemical properties and pH curve

The result of soil physico-chemical properties determined before sowing in both seasons is shown in Table 1. The pH of the soil indicates strongly acidic and the available phosphorus content of the soil described as low according to Hazelton and Murphy (2007).

Table 1. Physico-chemical properties of the study area before planting in 2012

Seasons	PH (1:25 H_20)	Total N (%)	OC (%)	Available P (ppm)	Exchangeable Cations Cmol(+)/kg soil				CEC (Cmol(+)/kg soil)	BS (%)
					Na	K	Ca	Mg		
Belg	4.9	0.20	2.9	6.47	0.09	0.14	10.1	11.3	26.9	80.2
Meher	4.7	0.20	2.7	6.16	0.11	0.17	14.5	1.08	24.7	64.0

N = nitrogen; OC = organic carbon; P = phosphorus; K = potassium; Na = sodium; Ca = calcium; Mg = magnesium; BS = base saturation

Table 2. Chemical properties of the compost used for the study

Compost	PH	N (%)	OC (%)	C:N	P (%)	K (%)	Ca (%)	Mg (%)
Belg	6.2	1.7	45.5	26.5	0.435	0.1098	0.658	0.286
Meher	6.0	1.5	41.8	27.3	0.428	0.1118	0.679	0. 279

N = nitrogen; OC = organic carbon; P = phosphorus; K = potassium; Na = sodium; Ca = calcium; Mg = magnesium; BS = base saturation

Based on the p^H curve, the CaO rate needed to raise the soil pH to the desired or optimum pH level for common bean *i.e* 6.5 (Wallace, 1980) was found to be 2.76 g kg^{-1}, which is equivalent to 5.426 g $CaCO_3$ (lime) kg^{-1} soil assuming 89% purity of lime, 20 cm plough depth and taking soil bulk density 1.18 g cm^{-3} was found to be equivalent to 1.28 tonne ha^{-1}(Figure 1).

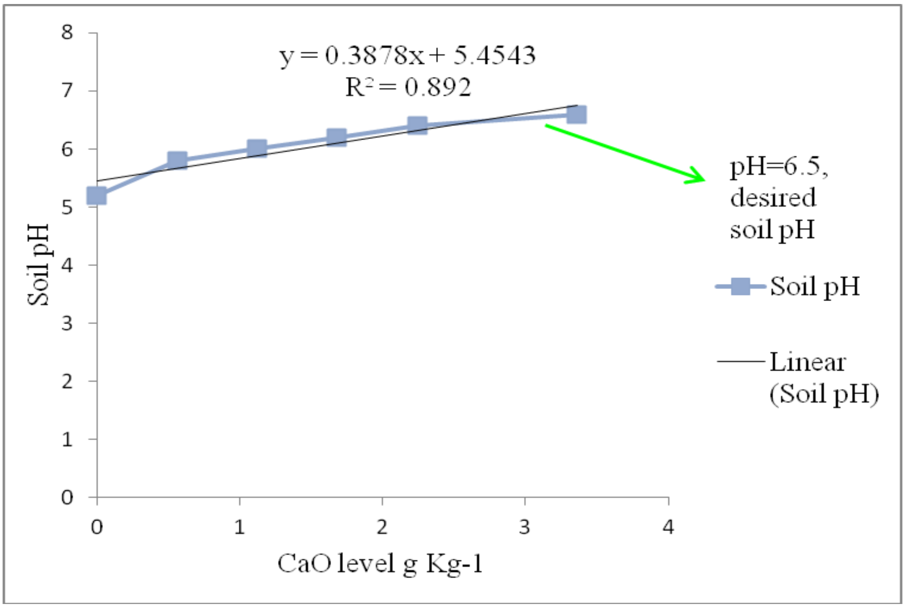

Fig 1. Soil pH plotted against CaO level

Effects on Yield and Yield Components

Above-ground biomass weight

The result showed that during both Meher and Belg seasons, combined application of compost with lime significantly increased aboveground biomass weight. The highest aboveground biomass was recorded for plots that received 10 tonnes ha^{-1} of compost along with 1.28 tonne ha^{-1} lime compared to the control (Table 3).

Table 3. Interaction effect of compost and lime on aboveground biomass of common bean during Meher and Belg seasons at Areka in 2013

Compost (tonnes ha^{-1})	Meher			Belg		
	Lime rates (tonne ha^{-1})			Lime rates (tonne ha^{-1})		
	0	0.64	1.28	0	0.64	1.28
0	3515.2^{f}	3756.7^{fe}	3864.2^{fed}	4846.3^{e}	5423.2^{ed}	5998.4^{cbd}
5	4396.9^{cbd}	4674.6^{cb}	4787.7^{b}	5497.5^{ed}	6114.3^{ed}	6452.8^{b}
10	4139.8^{ced}	4690.2^{cb}	6287.8^{a}	5599.8^{cd}	6234.8^{cb}	7503.1^{a}
LSD (0.05)	568.45			692.61		

The increase in aboveground biomass weight in both seasons might be ascribed to improved growth such as leaf area index and improvement in soil chemical properties especially soil pH and available calcium and magnesium due to application of lime along with compost. This result is supported by Fageria, (2008), Abay, (2011) and Manoj-Kumar *et al.,* (2012).

The results are in consistent with the findings of Verde (2014), who reported significantly higher stover and total dry matter yield of soybean as a result of combined application of 2.5 tonnes ha^{-1} manure along with 2 tonnes ha^{-1} lime. Moreover in Belg season, the combined application of lime and phosphorus significantly increased above-ground biomass yield (Table 4). Hence, the highest aboveground biomass yield ha^{-1} was obtained following application of 0.64 tonne ha^{-1} lime along with 46 kg P_2O_5 ha^{-1}, Better aboveground biomass weight production might be attributed to the positive effects of combined application of lime and phosphorus on availability of nutrients in the soil mainly phosphorus, which have critical role in many nucleotide based metabolic processes (Sinclair and Vadez, 1999) inducing cellulose and hemicelluloses synthesis and leaf area expansion (Fujita et al., 1999), which in turn result in higher photosynthetic efficiency, thereby leading to better growth and biomass accumulation (Fujita *et al.,* 1999). Fageria *et al.* (1995) also reported significant interaction effects of lime and phosphorus on the above ground weights of common bean, rice and corn.

Table 4. Interaction effect of lime and phosphorus on aboveground biomass weight of common bean during Belg season at Areka in 2013

Lime (tonne ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})		
	0	23	46
0	4308.6^{d}	5690.7^{cb}	5944.2^{cb}
0.64	5473.0^{c}	6081.7^{cb}	6217.6^{b}
1.28	5861.2^{cb}	7017.8^{a}	7075.3^{a}
LSD (0.05) = 617.28			

Effect of Compost, Lime, and Phosphorus on Yield and Yield components of Common bean

Number of pods per plant and number of seeds per pod

Number of seeds per pod also responded significantly to single application of compost, lime and phosphorus in Belg and only to single application of phosphorus in Meher season (Table 5). Hence, in the Belg season compared to the control, separate application of compost and lime at rates of 5 tonnes and 1.28 tonnes ha^{-1}, respectively produced a 7% higher number of seeds per pod (Table 5). Similarly, application of phosphorus at rates of 46 kg P_2O_5 ha^{-1} resulted in about 8 and 12% higher number of seeds per pod compared to the control in

Meher and Belg seasons, respectively. Similar to number of pods per plant, increase in number of seeds per pod is might be attributed to enhanced growth and development as a result of improved availability of nutrients leading to better partitioning of vegetative parts into yield attributing traits such as number of seeds per pod. Corroborating the findings significant increase in number of seeds per pod recorded for haricot bean (Amare *et al.,* 2014) and mash bean (Ali *et al.,* 2002) as a result of phosphorus application.

On the other hand, in Meher season, number of seeds per pod responded only to phosphorus application (Table 5). As a result, increasing the phosphorus rate from 0 to 46 kg P_2O_5 increased number of seeds per pod by nearly 17% over the control. The increase in seed number per pod might be associated with better growth performance of common bean due to improved availability of phosphorus following application of phosphorus. The result agrees with the findings of Ali *et al.* (2002), who reported significant increase in number of seeds per pod for mash bean following application phosphorus.

Table 5. Main Effects of compost , lime and phosphorus on Number of pods per plant, Number of seeds per pod and harvest index during Belg and Meher in 2013 at Areka

Compost (tonnes ha^{-1})	NSPP		HI (%)	
	Belg	Meher	Belg	Meher
0	4.3^{b}	4.0	33.5	36.4^{b}
5	4.3^{b}	3.8	35.6	39.0^{ba}
10	4.6^{a}	4.0	36.2	40.0^{a}
Lime (tonne ha^{-1})				
0	4.3^{b}	3.9	32.9^{b}	36.0^{b}
0.64	4.3^{b}	4.0	36.7^{a}	39.5^{a}
1.28	4.6^{a}	3.9	36.0^{a}	39.5^{a}
P (kg P_2O_5 ha^{-1})				
0	4.2^{b}	3.6^{b}	29.4^{b}	35.8^{b}
23	4.4^{b}	4.0^{a}	37.2^{a}	39.5^{a}
46	4.7^{a}	3.9^{a}	38.8^{a}	40.2^{a}
CV (%)	7.60	11.14	14.4	15.7
LSD (0.05)	0.183	0.2385	2.753	3.304

Application of lime along with phosphorus also significantly influenced number of pods per plant in Belg season (Table 6). Generally, an increasing trend in number of pods per plant was observed with increase in both lime and phosphorus rates. Hence, the maximum number of pods per plant was obtained by combined application of 1.28 tonnes ha^{-1} lime in combination with 46 kg P_2O_5 ha^{-1}, exceeding the control treatment by 68% (Table 6). The increment in number of pods per plant might be attributed to higher growth and development, which resulted in higher biomass accumulation in the same season resulting in better partitioning of biomass into yield attributing traits such as number of pods per plant in the later growth stages of the crop. Consistent with the results, Barasa *et al.,* (2013) observed positive lime × phosphorus interaction effects on fresh pod yields of French bean varieties.

Table 6. The interaction effect of phosphorus and lime on number of pods per plant during belg season at Areka in 2013

Phosphorus rates	Lime (tonne ha^{-1})		
(kg P_2O_5 ha^{-1})	0	0.64	1.28
0	9.4^{d}	12.6^{c}	
23	13.9^{bc}	14.8^{ba}	
46	14.0^{bc}	15.2^{ba}	
LSD (0.05) 1.5309			

In Meher season, combined application of compost with lime significantly influenced number of pods per plant (Table 7). Hence, application of compost and lime at corresponding rates of 10 and 1.28 tonnes ha^{-1} resulted in maximum number of pods per plant. The compost has relatively better nutrient content and the release of nutrients from the applied compost and improved availability through decomposition and effect of the applied lime might have contributed to the better growth of the crop resulting in increased number of pods per plant. The results are in conformity with the findings of Verde (2014) who observed significant increase in number of soybean pods over control as a result of combined application of manure at 5 t ha^{-1} and lime at 2 t ha^{-1} in the form of CaO.

Table 7. The interaction effect of compost and lime on number of pods/plant during Meher season at Areka in 2013

Compost	Lime (tonne ha^{-1})		
(tonnes ha^{-1})	0	0.64	1.28
0	10.4^{d}	11.6^{c}	13.5^{a}
5	12.0^{bc}	12.0^{bc}	12.2^{bc}
10	12.9^{ba}	12.3^{ba}	12.6^{a}
LSD (0.05)	1.1009		

Harvest index

In the Meher season, plots applied with the highest compost, lime and phosphorus rate recorded the maximum harvest index. Hence, increasing the rate of lime from 0 to 1.28 tonne ha^{-1} and phosphorus from 0 to 46 kg P_2O_5 ha^{-1} resulted in corresponding 24 and nearly 26% increase in harvest index compared to the control (Table 5). The increase in harvest index due to sole application lime and phosphorus might be attributed to relatively better partitioning of dry matter into grain yield. Corroborating the result, Wasonga *et al.,* (2008) recorded significant increase in harvest index of maize varieties over the control due to inorganic phosphorus application.

Table 8. Interaction effect of lime and phosphorus on harvest index during Belg season at Areka in 2013

Lime (tonnes ha^{-1}	Phosphorus level (kg P_2O_5 ha^{-1})		
	0	23	46
0	24.0^{d}	37.4^{ba}	37.2^{ba}
0.64	34.8^{b}	36.36^{ba}	38.8^{ba}
1.28	29.4^{c}	38.8^{ba}	40.2^{a}
LSD (0.05) = 617.28			

Harvest index was also influenced by the combined application of lime and phosphorus during the Belg season (Table 8). Hence, the highest harvest index, which exceeds the control by 68%, was recorded due to combined application of 1.28 tonne ha^{-1} lime along with 46 kg P_2O_5 ha^{-1}. In line with this, Verde (2014) recorded significantly higher harvest index of soybean than other treatments as a result of application of 2.5 tonnes ha^{-1} manure along with 30 kg P_2O_5 ha^{-1}.

Grain Yield

In Belg season, grain yield showed that it was significantly influenced by interaction of lime and phosphorus (Table 9). Result indicates that maximum grain yield was obtained with application of phosphorus at 46 kg P_2O_5 ha^{-1} along with lime at rate of 1.28 tonne ha^{-1} resulted in 174% higher grain yield compared to the control (Table 9). Hence, the positive response in grain yield due to combined application of lime and phosphorus might be linked to direct addition of P from the applied inorganic P and improved soil condition through the applied lime, which enhanced growth and development, thereby resulting in higher grain yield. The result of the study was in agreement with Fageria *et al.* (1995) and Wassie and Shiferaw (2009) who all reported a significant increase in crop yield including common bean on acid soils with the combined application of lime and phosphorus fertilizer.

Table 9. The interaction effect of lime and phosphorus on the grain yield of Common bean during Belg season at Areka in 2013

Lime (tonnes ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})		
	0	23	46
0	1033.0^{f}	2134.1^{cd}	2214.4^{dc}
0.64	1916.5^{de}	2191.0^{dc}	2432.8^{bc}
1.28	1736.7^{e}	2661.7^{ba}	2834.9^{a}
LSD (0.05)	374.39		

During the Meher season also combined application of compost and lime significantly increased grain yield ha^{-1} (Table 10). Accordingly, the highest grain yield ha^{-1} obtained as a result of application of 10 tonnes ha^{-1} compost along with 1.28 tonne ha^{-1} lime. The response in grain yield due to combined application of compost and lime might be linked to addition of nutrients from the applied compost through decomposition (Santos *et al.*, 2011) as well as from the soil applied lime (Fageria, 2008; Wasie and Shiferaw 2009; Abay, 2011; Manoj-Kumar *et al.*, 2012).

Table 10. Interaction effect of compost and lime on the grain yield of Common bean during the Meher season at Areka in 2013

Lime (tonnes ha^{-1})	Lime (Tonne ha^{-1})		
	0	0.64	1.28
0	1158.3^{c}	1389.8^{ed}	
5	1504.7^{d}	1887.7^{cb}	
10	1628.9^{cd}	1932.6^{b}	
LSD (0.05)	275.7		

Furthermore, the study also revealed that interaction between compost and phosphorus significantly improved grain yield during the Meher season (Table 11). Hence, combined application of compost and phosphorus at corresponding rates of 10 tonnes and 46 kg P_2O_5 ha^{-1} resulted in the highest grain yield ha^{-1} Increasing trend in grain yield due to combined application of compost and phosphorus might be attributed to improvement in soil nutrient status accompanying direct supply of phosphorus from the soil applied inorganic phosphorus and compost through decomposition (Wasonga *et al.*, 2008; Santos *et al.*, 2011). The findings of this study also agree with that of Al-Chammaa *et al.* (2014), where combined application of sheep manure and phosphorus resulted in significant increase in soybean grain yield over the control.

Table 11. Interaction effect of compost and phosphorus on grain yield (kg ha^{-1}) during the Meher season at Areka in 2013

Compost (tonnes ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})		
	0	23	46
0	1202.8^{c}	1419.0^{cb}	1421.1^{cd}
5	1534.4^{c}	1920.3^{b}	1948.8^{b}
10	1510.8^{c}	2143.9^{ba}	2325.0^{a}
LSD (0.05)=	278.01		

Economic analysis

The economic analysis of the treatments indicated that the application of 23 kg P_2O_5 ha^{-1} resulted in net benefit of 12211.5 and 369.2 ETB during Belg and Meher seasons respectively (Tables 12). Mupangwa and Tagwira (2000) had reported that application of 18.7 kg P_2O_5 ha^{-1} resulted in the highest rate of return from groundnut grown in acid sandy soils. This study result agrees with their findings.

Table 12. Economic analysis for different rates of phosphorus and fertilizer at current prices during Belg season in 2013 at Areka

Treatments	Seasons of the year					
	Belg			Meher		
	TCV (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)	TCV (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Lime (tonnes ha^{-1}) + Phosphorus (kg P_2O_5 ha^{-1})						
0+0	777.1	6071.7		-	-	-
0+23	1939.0	12211.5	528	-	-	-
0+46	2307.8	12374.1	44			
Compost + Lime (tonnes ha^{-1})						
0 + 0	-	-		871.4	7103.9	
0 + 0.64	-	-	-	2461	7107.5	0.22
Compost (tonnes ha^{-1}) + phosphorus ($kg^{-1}P_2O_5$)						
0+0	-	-	-	904.8	7376.6	
0+23	-	-	-	1401.0	369.2	200

Conclusion

The results of this study demonstrated that growth and yield parameters of common bean such as aboveground biomass, number of pods per plant and number of seeds per pod were improved as a result of application of compost, lime and phosphorus thereby resulting in significant increment in economic yield in both seasons. This implies the poor fertility status of the soils of the study area and the possibility of rectifying the problems through application of organic and inorganic nutrient source as well as liming. As a result, maximum grain yield per hectare was obtained as a result of combined application of the highest rates of lime and phosphorus, compost and phosphorus as well as compost with lime. In spite of this, application of phosphorus alone at rate of 23 kg P_2O_5 ha^{-1} is adequate to attain maximum profit of the crop at Areka in both seasons. In conclusion, considering short-term economic benefit of the farmers, application of the aforementioned rate of phosphorus can ensure short-term economic return for farmers in both seasons at Areka, while combined application of compost with lime or compost with phosphorus is beneficial for restoring the fertility of the soil, thereby improving and maintaining yield of the crop in the study are in a more sustainable way.

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