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Effect of Phosphorus Application and Varieties on Grain Yield and Yield Components of Common Bean (*Phaseolus vulgaris* L.)

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ABSTRACT

Common bean (*Phaseolus vulgaris* L.) is important pulse crop in Ethiopia. The low yield of common bean is party attributed to low phosphorus fertility of the soil. A field experiment was conducted at Hanaze village, Kindo Koysha district, Wolaita, Ethiopia, to determine grain yield and yield components and agronomic efficiency using factorial combinations of 4 P rates (0, 13.2, 26.4 and 39.6 kg ha^{-1} P) and 4 common bean varieties (Hawassa-Dume, Nasir, Omo-95 and Remeda) in randomized complete block design with 3 replications. With the increase in P rate from 0-39.6 kg ha^{-1}, seeds/pod increased from 3.27-3.77 whereas days to flowering and maturity reduced from 57-52 and 76-73, respectively. The respective increase in pods/plant and grain yield (kg ha^{-1}) with the increase in P rate from 0-39.6 kg ha^{-1} was from 2.40-17.00 and 719-1542 for variety Hawassa-Dume, Nasir 2.60-9.47 and 583-1469, Omo-95 from 2.27-6.53 and 604-1062 and Remeda 2.20-9.47 and 312-1276. Agronomic efficiency declined from 92-21, 60-22, 42-12 and 32-24, for varieties Hawassa-Dume, Nasir, Omo-95 and Remeda, respectively, with the increase in P rate from 13.2-39.6 kg ha^{-1}. The present experiment suggests that the soil P content would be assessed before fertilizer recommendation and variety Hawassa-Dume would be used in future to develop P efficient common bean varieties for P limited soils.

Key words: Common bean, phosphorus, grain yield, agronomic efficiency, *Phaseolus vulgaris*

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important pulse crop in Ethiopia occupying about 366,877 ha (19.69% of land area allocated to pulses) and producing about 463,008 tons of grain (16.83% of the total pulses production) (CSA., 2013). Average yield (1.26 t ha^{-1}) of common bean is low which is partly because phosphorus is deficient in about 70% of soils of Ethiopia (Mamo and Haque, 1991).

Phosphorus is a constituent of nucleic acids, phospholipids and ATP (Mengel and Kirkby, 2001; Marschner, 2012). It is however less available for plant uptake in most tropical soils mainly because of its fixation with Ca in alkaline soils and Fe and Al in acidic soils. Moreover, usually less than 15% of P fertilizer applied is recovered from the soil by the crop grown immediately after application (Greenwood, 1981). Even though addition of P fertilizer increases grain yield in many crops such as tef (Deressa *et al*., 2004; Balcha, 2014),wheat (Gunes *et al*., 2006), sorghum

(Akram *et al*., 2007), maize (Hussein, 2009), common bean (Fageria *et al*., 2010; Gidago *et al*., 2011; Girma *et al*., 2014; Kassa *et al*., 2014) and soybean (Devi *et al*., 2012), the application of excess P fertilizer has been associated with environmental pollution (Mengel and Kirkby, 2001; Marschner, 2012).

The differences in genotypes to grow in P limited soils have been reported in several crops such as wheat (Gahoonia *et al*., 1999; Osborne and Rengel, 2002; Ozturk *et al*., 2005), maize (Hussein, 2009) and common bean (Fageria *et al*., 2010) which may be due to differences in changing rhizosphere pH, release of organic compounds, root surface area (Lynch and Brown, 2001; Gahoonia and Nielsen, 2004), production and secretion of phosphatase enzymes by the roots (Yun and Kaeppler, 2001; Wasaki *et al*., 2003) and use of acquired P in dry matter production (Fohse *et al*., 1988; Clark and Duncan, 1991). The present experiment was conducted to determine grain yield and yield components and agronomic efficiency of common bean varieties at different P rates.

MATERIALS AND METHODS

This experiment was conducted on-farm at Hanaze village ($6^0$33'43"N, $37^0$76'27"E and 1180 meter above sea level), Kindo Koysha district, Wolaita, Ethiopia, from August-October, 2014 during main cropping season. The nearby town of Bale, 6 km from experiment site has average rainfall of 1129 mm per annum and the monthly average minimum and maximum temperatures of 21.2 and 30.7°C, respectively. During the experiment period, monthly average rainfall was 208 mm and monthly average minimum and maximum temperatures were 26.0 and 34.9°C, respectively. The soil of the experimental field at 0-30 cm depth is sandy loam (clay 14, silt 26 and sand 60%) with pH 5.1, total N 0.10%, organic carbon 1.15%, P 1.5 ppm (Olsen) and CEC 20.8 meq kg^{-1} soil.

Factorial combinations of 4 phosphorus rates (0, 13.2, 26.4 and 39.6 kg ha^{-1} P) and 4 common bean varieties (Hawassa-Dume, Nasir, Omo-95 and Remeda) were laid out in a randomized complete block design with 3 replications. Planting was done on August 5, 2014 on a plot of 4 rows having row length of 2 m. The distance between plots was 1 m and that between rows, plants within row and replications was 40 cm, 10 cm and 1.5 m, respectively. The P rates and 40 kg ha^{-1} N in the form of urea and diammonium phosphate were applied at planting time. Weeds were controlled with frequent hand weeding throughout the experiment. Days to flowering and maturity, pods/plant, seeds/pod, 100-seed weight (g) and grain yield (kg ha^{-1}) were recorded on 2 central rows.

Agronomic efficiency was calculated according to Mengel and Kirkby (2001) as:

$$AE = \frac{GYf - GYc}{Ps}$$

where, AE is agronomic efficiency, GYf is grain yield of fertilized plot, GYc is grain yield of control plot and Ps is fertilizer P supply.

The grain yield and yield components and agronomic efficiency data were analyzed using Genstat software (VSN International, 2012).

RESULTS

The effect of P and variety was significant for days to flowering and maturity, pods/plant, seeds/pod, grain yield and agronomic efficiency, whereas 100-seed weight was only significantly

($p<0.01$) affected by variety and the effect of P×variety interaction was significant ($p<0.01$) for pods/plant, grain yield and agronomic efficiency (Table 1).

With the increase in P rate from 0-39.6 kg ha^{-1}, seeds/pod increased from 3.27-3.77 whereas days to flowering and maturity reduced from 57-52 and 76-73, respectively. However, the change in these parameters with the increase in P rate beyond 13.2 kg ha^{-1} was not significant. The 100-seed weight was 17.50 g for varieties Nasir and Omo-95 and the rest was either 18.33 (variety Hawassa-Dume) or 27.08 g (variety Remeda). Variety Nasir was the latest to flower (55 days) compared to others (53 or 54 days) (Table 2).

Pods/plant increased from 2.40-17.00 for variety Hawassa-Dume, Nasir 2.60-9.47, Omo-95 from 2.27-6.53 and Remeda 2.20-9.47 with the increase in P rate from 0-39.6 kg ha^{-1}. However, the change in pods/plant with the change in P rate was not significant beyond 13.2 kg ha^{-1} P for varieties Nasir, Omo-95 and Remeda and beyond 26.4 kg ha^{-1} P for variety Hawassa-Dume. Variety Hawassa-Dume was significantly higher in pods/plant than the other varieties at all P rates except 0 kg ha^{-1} P. In average, pods/plant increased from 2.31-10.62 with the increase in P rate from 0-39.6 kg ha^{-1}. However, this increase was not significant beyond 26.4 kg ha^{-1} P (Table 3).

Table 1: Mean square values of 6 grain yield and yield components and agronomic efficiency of common bean grown during 2014 main cropping season

Sources of variation	df	Pods/plant	Seeds/pod	SW	GY	DTF	DTM	df	AE
Replication	2	4.33ns	1.38**	7.02ns	11121ns	1.52ns	13.15*	2	248ns
Phosphorus(P)	3	171.92**	1.25**	0.74ns	1932578**	57.39**	28.91**	2	4354**
Variety (V)	3	72.10**	0.75*	261.63**	833848**	9.28*	8.91ns	3	955**
P×V	9	10.75**	0.41ns	11.11ns	104250**	2.37ns	2.50ns	6	547**
Error	30	3.18	0.21	5.38	26524	2.14	2.99	22	65
CV, %		23.00	12.20	11.50	14.10	2.70	2.40		22

*,**: Significant at $p< 0.05$ and $p<0.01$, respectively, Ns: Not-significant, DTF: Days to flowering, DTM: Days to maturity, SW: 100-seed weight (g), GY: Grain yield (kg ha^{-1}), AE: Agronomic efficiency, df: Degree of freedom

Table 2: Mean values of seeds/pod, 100-seed weight and days to flowering and maturity of common bean for four P rates and four varieties grown during 2014 main cropping season

P rate (kg ha^{-1})	Seeds/pod	100-seed weight (g)	Days to flowering	Days to maturity
0	3.27	20.00	57	76
13.2	3.98	20.42	53	73
26.4	3.91	20.17	52	73
39.6	3.77	19.83	52	73
Mean	3.73	20.10	54	74
$LSD_{0.05}$	0.38	ns	1.22	1.44
Variety				
Hawassa-Dume	3.83	18.33	53	73
Nasir	3.65	17.50	55	74
Omo-95	4.02	17.50	53	73
Remeda	3.43	27.08	54	74
Mean	3.73	20.10	54	74
$LSD_{0.05}$	0.38	1.93	1.22	ns

Ns: Not-significant

Table 3: Pods/plant of common bean as affected by P×variety interaction during 2014 main cropping season

	P rate (kg ha^{-1})				
Variety	0	13.2	26.4	39.6	Mean
Hawassa-Dume	2.40	11.20	14.53	17.00	11.28
Nasir	2.60	7.33	9.53	9.47	7.23
Omo-95	2.27	6.53	7.13	6.53	5.62
Remeda	2.20	6.53	9.40	9.47	6.90
Mean	2.37	7.90	10.15	10.62	

$LSD_{0.05}$ for P and variety was 1.49 and for P×variety was 2.97

Table 4: Grain yield (kg ha^{-1}) of common bean as affected by P x variety interaction during 2014 main cropping season

	P rate (kg ha^{-1})				
Variety	0	13.2	26.4	39.6	Mean
Hawassa-Dume	719	1927	1740	1542	1482
Nasir	583	1375	1438	1469	1216
Omo-95	604	1156	1406	1062	1057
Remeda	312	781	1061	1276	858
Mean	555	1310	1411	1337	1153

$LSD_{0.05}$ for P and variety was 136 and for P×variety was 272

Table 5: Agronomic efficiency of common bean as affected by P×variety interaction during 2014 main cropping season

	P rate (kg ha^{-1})			
Variety	13.2	26.4	39.6	Mean
Hawassa-Dume	92	39	21	50
Nasir	60	32	22	38
Omo-95	42	30	12	28
Remeda	36	28	24	29
Mean	57	32	20	37

$LSD_{0.05}$ was 6.80,7.86 and 13.61, for P rate, variety and P×variety, respectively

Grain yield increased with the increase in P rate from 0-39.6 kg ha^{-1} for varieties Hawassa-Dume 719-1542, Nasir 583-1469, Omo-95 from 604-1062 and Remeda 312-1276 kg ha^{-1}. However, the grain yield increase was not significant beyond 13.2 and 26.4 kg ha^{-1} P rates for varieties Nasir and Remeda, respectively and the decline in it was not significant beyond 13.2 and 26.4 kg ha^{-1} P rates for varieties Hawassa-Dume and Omo-95, respectively. In average, grain yield increased from 555-1337 kg ha^{-1} with the increase in P rate from 0-39.6 kg ha^{-1} despite the change in it with the increase in P rate beyond 13.2 kg ha^{-1} was not significant (Table 4).

Agronomic efficiency declined from 92-21, 60-22, 42-12 and 36-24, for varieties Hawassa-Dume, Nasir, Omo-95 and Remeda, respectively, with the increase in P rate from 13.2- 39.6 kg ha^{-1}. In average, 13.2, 26.4 and 39.6 kg ha^{-1} P rates showed the agronomic efficiency of 57, 32 and 20, respectively (Table 5).

DISCUSSION

As to the present experiment, the existence of genotypic variation in grain yield and yield components (Fageria *et al*., 2010; Girma *et al*., 2014; Zewdu, 2014) and the delay in days to maturity (Gidago *et al*., 2011) with the limited P supply have been reported for common bean. The early flowering with the supply of P observed in present experiment agrees with the report for tomato (Menary and Staden, 1976), wheat (Rahman and Wilson, 1977) and tef (Balcha, 2014). This could be because of increased cytokinins synthesis (Horgan and Wareing, 1980) and supply of photosynthates (Marschner, 2012) for flower formation. Perhaps, P deficiency has been related to the reduction in foliar expansion (Fredeen *et al*., 1989), decrease in the number of leaves (Lynch *et al*., 1991) and loss in photosynthetic efficiency (Lauer *et al*., 1989).

As to the present experiment, the increase in P rate increased pods/plant, seeds/pod and grain yield for common bean (Kassa *et al*., 2014; Turuko and Mohammed, 2014) and soybean (Devi *et al*., 2012). However, the low increase or decline in these parameters beyond 13.2 kg ha^{-1} P rate despite the low soil P content (1.5 ppm) observed in present experiment could be related to the reaching of P supply to the optimal level or limitation of yield potential of bean varieties studied. Perhaps, with the increase in one nutrient, the availability of other nutrients or the genetic potential of the plants become the limiting factors (Marschner, 2012).

As to the present experiment, the decrease in agronomic efficiency with the increase in P supply has been reported for maize (Hussein, 2009), common bean (Gidago *et al*., 2011; Girma *et al*., 2014), soybean (Devi *et al*., 2012) and tef (Balcha, 2014). This could be due to the limiting effect of other nutrients with increasing level of P (Mengel and Kirkby, 2001), or because the rate of increase in grain yield was less than the rate of increase in P supply. The present experiment suggests that the soil P content would be assessed before fertilizer recommendation and variety Hawassa-Dume would be used in future to develop P efficient bean varieties for P limited soils.

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