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THE RESPONSE OF HARICOT BEAN VARIETIES TO DIFFERENT RATES OF PHOSPHORUS AT ARBA MINCH, SOUTHERN ETHIOPIA

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ABSTRACT

Field experiment was conducted during 2013 to determine the response of common varieties to phosphorus fertilizer application. The treatment consists of three common bean varieties (Hawassa Dume, Ibbado and Nasir) and three phosphorus rates (0, 20 and 40 kg P_2O_5 /ha) laid out in Randomized Complete Block Design with three replications. Data was collected on plant height (cm), number of nodule/plant, dry matter, number of pods/plant, number of seeds/pod, 1000 seed weight (g), seed yield (kg/ha), harvest index, crude protein content and phosphorus uptake. The increasing rates of fertilizer showed substantial improvement in nodule number, seed yield, crude protein content, fertilizer recovery, agronomic efficiency and physiological efficiency where the highest values of these parameters were obtained from fertilizer at the rate of 20 kg P_2O_5/ha. Hawasa dume showed the best performance in most parameters whereas Ibbado gave the lowest performance in contrary. These results can indicate the benefit of phosphorus fertilizer application and variety consideration for yield improvement, nodulation potential and better nutrient use efficiency of common in the study area.

Keywords: phosphorus, haricot bean, Ethiopia.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important food and export crop in Ethiopia and it is the source of protein and cash for poor farmers (Dereje *et al*., 1995).

Phosphorus is the most important element for adequate grain production (Brady and Weil, 2002); next to nitrogen. An adequate supply of P early in the life of a plant is important in the development of its reproductive parts. Large quantities of P are found in seed and fruit, and it is considered essential for seed formation. A good supply of P is associated with increased root growth. P is also associated with early maturity of crops, particularly grain crops. The quality of certain fruit, forage, vegetable, and grain crops is improved and disease resistance increased when these crops have satisfactory P nutrition (Havlin, *et al*., 1999).

Legumes including haricot bean have high P requirement due to the production of protein containing compounds, in which N and P are important constituents, and P concentration in legumes is generally much higher than that found in grasses. High seed production of legumes primarily depends on the amount of P absorbed (Khan *et al*., 2003). The yield of haricot bean increases with P application (Gemechu, 1990) and its nodulation can be improved with the application of phosphorus (Amare, 1987). Getachew (1990) reported that lack of optimum fertilizer rate is one of the several factors contributing to the low grain yield of the bean. Hence, determination of optimum rate of phosphorus is essential to maximize the yield of bean.

The aim of this study was to evaluate the influence of different rates of phosphorus on yield, yield attributes and protein content of common varieties.

MATERIALS AND METHODS

Description of the study area

The research will be conducted in Southern Nations, Nationalities and Peoples` Regional (SNNPR) State. The study area has an altitude around 1290 masl. The rainfall pattern of the study area is a bimodal type with a total precipitation of 830.7 mm per annum. The major peak in April and small peak in October (Tuma, 2007), that extends from April to October with maximum fall in the months of June, July and August. The mean minimum, mean maximum and average temperatures are 14.1, 27.9 and 20.6^0 C, respectively.

Experimental design, land preparation and treatments

Field experiment was conducted each at Arba Minch university research farm during 2013 in Randomized Complete Block Design with three replications. Firs land was selected, then ploughed and divided into three blocks each having each having nine plots and the individual plot was arranged to have an area of $4.8m^2$. The distance between blocks and plots will be maintained to be 2m and 1m, respectively. Three common bean varieties (Hawassa Dume, Nasir and Evado) were sown at spacing of 40cm between rows and 10cm between plants. Three phosphorus rates (0, 20 and 40 kg P_2O_5 /ha) were used. All levels of phosphorus were applied at sowing time with 30kg/ha starter nitrogen. Crop management practices such as gap filling; weeding, thinning and plant protection measure were done as per requirement.

Soil sampling and analysis

Before sowing, soil samples was taken from representative points within the block at 30 cm depth to make one composite surface soil sample analysis of soil texture, pH, organic carbon, available P, total N and cation exchange capacity analyzed at JIJE analytical laboratory. The results of soil analysis are indicated in Table-1.

Table-1. Some physical and chemical properties of the soil of the experimental site.

pH (H_2O) (1:2.5)	OM (%)	Tot. N (%)	Avai P ppm	Exchangeable cations cmol/kg				CEC cmol/kg	Textural class
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		
6.6	2.4	0.196	8.04	12.05	7.54	0.913	2.5	48.6	Clay loam

Data collection

Data was collected on plant height, number of nodules/plant, dry matter, number of pods/plant, number of seeds/pod, 1000seed weight, harvest index and seed yield.

Plant analysis

Total P analysis of whole plant at maturity was carried out on the plant sampled for grain and biological yield determination at harvest. Plant samples were composited treatment-wise from three replications. They were then ground to pass through a 40-mesh screen. After treating the ashed material, phosphorus content in the plant tissue was determined.

Apparent fertilizer P recovery, Agronomic and physiological P use efficiencies were calculated by using procedures described by Craswell and Godwin (1984). Protein content was determined by the micro-Kjeldahl method.

Data analysis

Data were subjected to the analysis of variance (ANOVA) appropriate to the design of the experiment (Gomez and Gomez, 1984) using SAS 9.1.3. Least significance difference test (LSD) at 5% level of probability was used to delineate the significant differences between and/or among treatment means.

RESULTS

Main effects of variety and fertilizer rates

Plant height (cm)

Significant differences (P< 0.01) in plant height were recorded among the varieties of haricot bean in this experiment. However, the response of plant height to the different rates of phosphorus was not significant (P> 0.05) (Table-2). Regarding variety effect, the highest value for plant height was recorded with Nasir variety (58.72cm) while the lowest value of plant height was recorded with Ibbado variety (41.70cm). But, the differences in plant height between Hawassa Dume and Ibbado varieties were observed to be statistically at par.

Nodule number/plant

Nodule number was significantly (P<0.01) affected by variety, phosphorus levels and their interaction effect (Tables 2 and 3). Regarding main effect, nodule number was significantly increased with increasing levels of phosphorus where the lowest (12.89) and the highest (31.85) significant values of this parameter were obtained from the control treatment and application of 20 kg P_2O_5/ha, respectively. The effects of 20kg P_2O_5/ha and 40 kg P_2O_5/ha were statistically at par. Similarly, the minimum and maximum significant nodule numbers were recorded due to Ibbado (3.82) and Nasir (37.13), respectively (Table-2). The difference between Dume and Nasir was statistically at par. Numerically, Nassir variety gave the highest nodule number.

Dry matter (kg/ha)

Dry matter was observed to be significantly (P<0.01) affected only by the main effects of variety and fertilizer (Table-2).

The minimum (3764 kg/ha) and maximum (4384 kg/ha) significant values of total dry matter were obtained from the control treatment and application of 20 kg P_2O_5/ha, respectively. However, increasing phosphorus rate beyond 20 kg P_2O_5/ha did not produce any further significant variation on total dry matter. Regarding variety, Nasir produced the highest significant total dry matter (4495 kg/ha) while Ibbado gave the lowest value.

Similar to total dry matter, pod number was also observed to be significantly affected only the main effects of by varieties (P<0.01) and phosphorus (P<0.05) levels (Table-2).

Pod number/plant

Application of phosphorus at 40 kg P_2O_5/ha produced the maximum significant pod number (19.011) while the lowest number of pods (12.944) was obtained from the control treatment (Table-2). The maximum and minimum values of pod number were recorded due to H. Dume (19.21) and Ibbado (10.81), respectively.

Seed number/pod

On the other hand, the number of seeds/pod was significantly (P<0.01) affected only by variety (Table-2). The effect of fertilizer levels and their interaction with variety was not significant (P>0.05). Dume variety produced the highest significant number of seeds/ pod (5.367) followed by Nasir (5.16) whereas Ibbado produced the least seed number/pod (4.022).

1000 Seed weight (g)

The main effects of variety and fertilizer rates showed significant differences (P< 0.01) in 1000 seed weight (Table-2). Concerning main effects of varieties, Ibbado gave the maximum significant 1000 seed weight (388.67g) followed by Nasir (197.43g) while Dume produced the lowest 1000 seed weight (174.90).

The increasing doses of phosphorus resulted in significant increment in 1000 seed weight. The highest (253.67g) and lowest values (253.17g) of 1000 seed weight due to fertilizer treatment were recorded from the control and from application of 40 kg P_2O_5/ha, respectively (Table-2).

Seed yield (kg/ha)

Significant difference in seed yield was recorded due to variety and fertilizer levels (Table-2). Maximum significant seed yield (2376 kg/ha) was recorded from variety Dume followed by Nasir (2246kg/ha). Ibbado gave the lowest seed yield (1924 kg/ha) (Table-2).

Yield significantly increased with increasing levels of phosphorus resulting in maximum significant (2326 kg/ha) value at the rate 20 kg P_2O_5/ha. However, the increment in fertilizer level beyond this rate did not significantly increase yield. The minimum value for seed yield (1922kg/ha) was obtained from the control treatment for each variety.

Harvest index

Similar to the number of seeds/pod, the variation in harvest index was significant (P< 0.01) only in response to variety (Table-2).

Fertilizer rate did not produce any significant effect on harvest index (Table-2). However, numerical increment was observed due to fertilizer treatment where the lowest value of harvest index was recorded at the control treatment for each variety. Regarding varieties,

Ibbado produced the highest harvest index (0.56) followed by H. Dume (0.53) while the least value was recorded from Nasir (0.50).

Table-2. Main effect of variety and phosphorus rates.

Variety	**PHT** (cm)	**NN**	**DM** (kg/ha)	**NP**	**NSP**	**TSW** (g)	**HI**	**Seed yield** (kg/ha)
H. Dume	46.51a	32.39a	4512a	19.21a	5.37a	174.00a	0.53ab	2376a
Ibbado	41.70a	3.82b	3478b	10.81b	4.02b	388.67b	0.55a	1924b
Nasir	58.72b	37.13a	4495a	17.62a	5.16a	197.43c	0.50b	2246c
LSD0.01	6.98	4.997	217.56	4.59	0.55	0.2954	0.027	63.73
P rates (kg/ha)								
0	46.18	12.89c	3764c	12.94c	4.73	253.17d	0.51	1922d
20	51.85	31.85d	4384d	15.68cd	4.93	253.57e	0.53	2326e
40	48.90	28.60d	4336d	19.01d	4.88	253.67f	0.53	2297e
LSD 0.05	ns			4.12	ns		ns	
LSD 0.01		4.997	217.56			0.2954		63.73
LSD 0.001								
CV	14.27	20.45	5.23	28.91	11.50	0.12	5.17	2.92

Means within row followed by the same upper case letters are not not significantly different at P<0.05
ns - nonsignificant; PHT-plant height; NN-number of nodule/plant; DM-dry matter; NP- number of pod/plant; NSP-number of seed/pod; TSW- 1000seed weight and Hi- harvest index.

Interaction effects of variety and fertilizer

Among the measure parameters under this study, only number of nodules/plant, 1000seed weight and seed yield were significantly affected by the interaction effect of variety and fertilizer (Table-3).

The increasing rates of fertilizer were observed to be associated with significant increment in all of these parameters. The maximum values were obtained from application of 20kg P/ha for each variety.

Table-3. Interaction effect of variety and phosphorus rates.

Variety	Hawassa Dume			Ibbado			Nasir		
P rates (kg/ha)	**0**	**20**	**40**	**0**	**20**	**40**	**0**	**20**	**40**
NN	22.0c	34.63b	40.53b	1.00e	2.33e	8.13de	15.67cd	58.60a	37.13b
$LSD_{0.01}$	8.65								
CV	20.45								
TSW(g)	173.7e	174.3d	174.9c	388.6a	388.9a	388.50a	197.2b	197.5b	197.6b
$LSD_{0.05}$	0.51								
CV	0.12								
SY (kg/ha)	2090.5c	2553.8a	2483.7ab	1762.7e	2013.5cd	1997.84cd	1916.48d	2412.55b	2410.3b
$LSD_{0.05}$	110.39								
CV	2.92								

Means within rows followed by the same lower case letters are not significantly different at P<0.05
NN- number of nodule/plant; TSW-1000 seed weight

Crude protein content

Increasing fertilizer treatment resulted in increment in crude content of haricot bean varieties (Table-4). Maximum increment in crude protein content was obtained from increasing fertilizer rate up to 20kg P_2O_5/ha for each variety. For all varieties the minimum crude protein content was obtained from the application of 0 kg P_2O_5 /ha. 11.4%, 18.9 % and 20.9% increment in crude protein content was recorded from Dume, Ibbado and Nasir varieties, respectively, due to application of phosphorus at the rate of 20kg P_2O_5/ha when compared with the control treatment.

Table-4. Effect of phosphorus on crude protein content (%).

P rate (kg/ha)	**H. Dume**	**Ibbado**	**Nasir**	
0	20.81	18.56	19.69	
20	23.19	22.06	23.81	
40	23.19	20.38	22.06	

Phosphorus uptake, allocation and use efficiency

Considerable differences in phosphorus uptake and allocation were observed among the varieties due to different rates of fertilizer application (Table-5). For each variety with each level of fertilizer, grain phosphorus level was greater than straw phosphorus level. Increasing phosphorus rates from 0 to 40 kg/ha increased grain phosphorus content from 0.49 to 0.82% for H. Dume, 047 to 0.77% for Ibbado and 0.45 to 0.68% for Nasir, respectively.

Moreover, the maximum phosphorus content in straw was recorded due to application of

40 kg/ha from H. Dume (0.63%) followed by Ibbado (0.61%) whereas Nasir (0.57%) gave the least.

In all varieties, consistent values of apparent fertilizer recovery and agronomic and efficiency were observed with increasing phosphorus rates (Table-5). Maximum values fertilizer recovery, agronomic efficiency and physiological efficiency were recorded from the application of 20 kg P_2O_5 /ha for each variety.

Accordingly, variety H. Dume gave the highest value of recovery (62%) and agronomic efficiency (44.55%) followed by followed by Ibbado which produced 51% fertilizer recovery and 33.35% agronomic efficiency. Nasir gave the lowest value of fertilizer recovery (27%) and agronomic efficiency (20.75%).

On the other hand, maximum value of physiological efficiency was obtained from Nasir (76.85) followed by H. Dume (71.85%) whereas Ibbado gave the lowest (65.39%) (Table-5).

Table-5. Phosphorus content, apparent recovery and use efficiency.

Variety	P (kg/ha)	Yield (kg/ha)		P content (%)		P uptake (kg/ha)			AFR (%)	AE (%)	PE (%)
		Grain	Straw	Grain	Straw	Grain	Straw	Total			
H. Dume	0	2091	2018	0.49	0.44	10.25	8.88	19.13	------	------	------
	20	2554	2265	0.75	0.55	19.16	12.46	31.61	62	44.55	71.85
	40	2484	2125	0.82	0.63	20.37	13.39	33.76	37	25.30	68.38
Ibbado	0	1917	2002	0.47	0.43	9.01	8.61	17.62	------	------	------
	20	2413	2325	0.65	0.52	15.68	12.09	27.77	51	33.35	65.39
	40	2410	2418	0.77	0.61	18.56	14.75	33.31	39	23.88	61.22
Nasir	0	1763	1501	0.45	0.39	7.93	5.85	13.79	------	------	------
	20	2014	1582	0.60	0.45	12.08	7.12	19.20	27	20.75	76.85
	40	1998	1575	0.68	0.57	13.59	8.98	22.56	22	14.15	64.32

AFR=apparent fertilizer recovery; AE=agronomic efficiency and PE= physiological efficiency.

DISCUSSIONS

The improvement in nodule number due to phosphorus fertilizer is could be associated with its stimulating effect on growth as described by (Tang *et al.*, 2001). The variation in varieties in nodule number under fertilizer treatment could be related to inherent symbiosis characteristics of the varieties (Taylor and Francis, 2005).
The significant increment in total dry mater might be ascribed to improvement in yield and yield components as demonstrated by Malik *et al.* (2006). Regarding varieties, the response to applied P could be attributed to genotypic characteristics.

The improvement in the number of pods due to phosphorus could be resulted from availability of plant nutrient which stimulated the plants to produce more pods per plant as compared to other treatments as phosphorus strongly encourages flowering and podding (Zafal *et al*., 2003).

Dume and Nasir gave higher number of seeds per pod than Ibbado which is in line with the report of Kindie (1997) who indicated that small seeded genotypes produced higher number of seeds per pod.

The improvement in 1000 seed weight with fertilizer application is in agreement with the finding of Shamim and Naimat (1987) who related the increment in 1000-seed weight to the influence of cell division, phosphorus content in the seeds as well as the formation of fat and albumin.

The out performance of Ibbado variety in 1000 seed weight is associated with the size of the seed is in accordance with Hawtin *et al.* (1980) who explained that the larger the seed, the higher its seed weight.

Grain yield is a product of several yield components including the number of pods/plant seeds/plant and seed weight (Heinrich *et al.*, 1983). Variety Dume gave the highest seed yield which was due to large number of seeds per pod (Kindie, 1997).

The main effect of variety gave the highest value of harvest index on variety Ibbado which is associated with greater 1000 seed weight of this variety and lower value of total dry matter accumulation when compared with the rest varieties. This is further supported by negative correction between harvest index and dry matter but positive and significant correlation between 1000 seed weight and harvest index (Table-6).

On the other hand, the numerical increment in harvest index with rates of fertilizer is in agreement with the findings of Chiezey *et al.* (1992) who related lower value of harvest index at low level of phosphorus application to poor development of plants at different growth stages.

The increment in crude protein content of common bean varieties may be associated with enhanced growth of roots and accumulation of dry matter and protein in the seeds (Lhuiller-Soundele *et al*., 1999). This is also further supported by positive and significant correlation of crude protein content with total dry matter (r=0.8143) and seed yield (r= 0.9078).

Correlation between traits

Number of nodules showed positive and a highly significant (P<0.001) relationship with total dry matter accumulation (r= 0.9189). It is also clearly observed that the increment in seed yield under this experiment due to phosphorus application is resulted from improvement in total dry matter accumulation, number of pods/plant and number of seeds/pod which is supported by positive and significant relationship of seed yield with total dry matter accumulation (r=0.9488), number of pods/plant (r= 0.7921) and number of seeds/pod (r=0.7305) (Table-6). But, seed yield showed negative relationship with 1000 seed weight and harvest index indicating implying that variety which has the highest 1000 seed weight (Ibbado) would give the lowest seed yield. Crude protein content also showed positive and significant relationship with number of nodules/plant (r=0.7981), total dry matter accumulation (r=0.8143) and seed yield (r=0.9078).

Negative and highly significant ($p<0.001$) relationship was observed between 1000 seed weight and number seeds/pod (r=-0.9027) which is in agreement with the findings of Kindie (1997). Crude protein content also showed negative relationship with 1000 seed weight (r=0.5123) which is in line with the report of Saxena *et al*., (2002).

Table-6. Association between various traits.

	PHT	Br	NN	DM	NP	NSP	TSW	SY	HI
PHT									
Br	-0.3281ns								
NN	0.6869*	-0.2836ns							
DM	0.6156ns	-0.1971ns	0.9189***						
NP	0.5359ns	-0.2103ns	0.7655*	0.7899*					
NSP	0.5016ns	-0.4509ns	0.8781**	0.8367**	0.6580ns				
TSW	-0.5819ns	0.5899ns	-0.7735*	-0.8419**	-0.7281*	-0.9027***			
SY	0.4564ns	0.0285ns	0.8603**	0.9488***	0.7921*	0.7305*	-0.6917ns		
HI	-0.6475ns	0.7400ns	-0.4725ns	-0.4842ns	-0.2864ns	-0.5927ns	0.7372*	-0.1847ns	
Protein	0.4892ns	0.2613ns	0.7981**	0.8143**	0.6903*	0.6202ns	-0.5123ns	0.9078***	-0.0145ns

**** - Correlation is significant at 0.001 level
** - Correlation is significant at 0.01 level
* - Correlation is significant at 0.05 level
ns- Correlation is non-significant at 0.05 level
PHT- plant height, Br- number of branches/plant; NN- number of nodules/plant; DM – total dry matter (kg/ha); NP- number of pods /plant; NSP- number of seeds/pod; TSW- 1000 seed weight (g); SY- seed yield (kg/ha) and HI-harvest index.

Generally, all the varieties had different uptake and allocation for application of phosphorus. This appears to indicate that there is an inherent varietal difference in P uptake and thereby protein production as reported by Tesfahun (2007).

Moreover, these observations are in agreement with the finding of Loneragan (1978) who reported that the differences among crop varieties in their ability to absorb phosphorus from soils may be due to at least three distinct root attributes; the physiological activity to absorb P from dilute solution; metabolic activity resulting in solubilization of absorbed P; and the ability of the root system to explore the soil phosphorus.

CONCLUSIONS AND RECOMMENDATION

Hawassa Dume variety showed the best performance followed almost in all measured parameters followed by Nasir where as Ibbado showed the least except in 1000seed weight and harvest index. Generally, application of phosphorus at the rate of 20kg P_2O_5 was the best in all parameters which were measured under this study on each variety.

These results revealed the benefit of phosphorus fertilizer application and variety consideration for yield improvement, nodulation and better nutrient use efficiency of common in the study area.

However, this study was undertaken during single season using only few varieties. Therefore, in order to come up with conclusive recommendation, it is important to repeat the study over different locations and seasons using additional rates of phosphorus, additional improved varieties and including other parameters of growth and at different growth stages.

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