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Full Length Research

Evaluation of common bean varieties at P deficient and sufficient conditions in Southern Ethiopia

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Field trials were conducted for two consecutive years from 2012 to 2013 at Amaro and Inseno testing sites of Awassa Agricultural Research Center to investigate the performance of common bean varieties under P deficit and sufficient conditions. Treatments consisted of P fertilizer (P_0 = without P fertilizer and P_1= 30 kg/ha P_2O_5) and 10 released haricot varieties (Tabor, AFR-702, Awash-1, Nasir, Awash melkasa, SARI-1, Omo-95, Dimtu, Awassa dume and Ibado). The treatments were arranged in a split plot design where P levels as main plot and haricot bean varieties as sub plots replicated three times. P fertilizer, common bean varieties and their interactions influenced yield and yield components of the common bean. Nasir produced the highest number of pods per plant at Amaro while Awash-1 yielded the greatest number of pods per plant at Inseno. The greatest TSW was recorded for Ibado which was followed by AFR-702 at both locations. Awassa dume gave the highest yield at both locations followed by Omo-95 at Amaro and Nasir at Inseno. Base on this finding, Awassa dume and Omo-95 for Amaro and Awassa dume and Nasir for Inseno could be best choice for respective locations.

Key words: Common bean varieties, P fertilizer, treatments.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important pulse crops cultivated in central, southern, eastern and western lowland and mid altitudes of Ethiopia. It is grown primarily for its dry seeds, green pods (as snap beans), and green-shelled seed. Young tender leaves and flowers are also utilized as fresh vegetables in some Central and Eastern African, and in Latin America countries (Kay, 1979; Singh, 1999). The world demand for haricot bean is ever increasing due to its significant role in human nutrition as a source of proteins, complex carbohydrates, vitamins and minerals (Bennink, 2005). In Ethiopia, common bean is a source of protein, cash crop and export commodity that generate foreign exchange for the country and predominantly produced for cash in the central rift valley (CACC, 2002). Currently, common beans cover the greatest part of the Ethiopiaՙs pulses export depending on external demand for quality (Gezaheng and Dawit, 2006).

Improved common bean production encompasses proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate and pesticide application as per recommendations (Alemitu, 2011). Low soil fertility is one of the major factors affecting common bean production in the central valley of Ethiopia. In general, the most critical production limiting nutrients in the low moisture stress areas of Ethiopia are nitrogen and phosphorus (Kidane, 1987; Asnakew, 1991). Phosphorus is the most important element for proper grain production and its adequate supply at early life of a plant is essential in the development of its reproductive parts (Brady and Weil, 2002). Legumes including common bean have high P requirement due to production of protein containing compounds which N and P are major constitutes, where P concentration in legumes is generally much higher than that found in grasses. High seed production of legumes is primarily dependent on the amount of P absorbed (Khan et al., 2003). The presence of large quantities of P in seed and fruit is an indication of essentiality of P in seed formation. A proper supply of P is associated with increased root growth and early maturity of crops, particularly grain crops. Indeed, the quality of certain fruits, forages, vegetables and grain crops is improved and disease resistance increased when these crops have satisfactory P nutrition (Havlin et al., 1999).

A wide range of common bean genotypes are grown in Ethiopia including mottled, red, white and black varieties (Ali et al., 2003). The most known commercial varieties currently in production include pure red and pure white colored beans with increasing market demand (Ferris and Kaganzi, 2008). In Ethiopia, pulse crops rank second as food after cereals, most farmers spare fertilizer for cereal production while pulses are grown on marginal soils usually as rotation crops (Adensina and Zinnah, 1993). Common bean, as a pulse is primarily a crop of small scale producers and generally common bean is primarily a crop of small scale producers and generally few inputs are used or no fertilizer or no soil amendments (Wortman et al., 1995). It is adapted to a wide range of climatic condition ranging from sea level to nearly 3000 m above sea level (m.a.s.l.) depending on variety selection. However, it does not grow well below 600 m because of poor pod setting caused by high temperature (Dev and Gupto, 1997).

Bean productivity is greatly influenced by soil fertility especially phosphorous because phosphorus plays an important role in biological nitrogen fixation (Jakobson, 1985; Hamdi, 1999). Phosphorus appears essential for both nodulation and N_2 fixation (Ssali and Keya, 1983). It is also the basis for the formation of useful energy, which is essential for sugar formation and translocation. Nitrogen fixation in beans needs more inorganic phosphorus and phosphorus availability in soil is considered to be the major constraint to common bean production (Israel, 1987). Hence, this trial was initiated to investigate the performance of common bean varieties under P deficit and sufficient conditions.

MATERIALS AND METHODS

Experimental site

Field trials were conducted for two consecutive years from 2012 to 2013 at Amaro (Clay loam textured soil with a pH of 6.5, 0.26% total Nitrogen (N), 39 ppm available phosphorous (P), 40.4 ppm available potassium (K) and altitude of 1400 masl and Inseno (Clay loam textural class soil with pH = 5.9, EC = 0.085 ds/m, CEC = 21.8 me/100 g soil, total N(%) = 0.118, available P 6.4 ppm, available K 48.2 ppm and OC (%) = 2.7) testing sites of Awassa Agricultural Research Center.

Treatments and experimental design

Treatments consisted of P fertilizer (P_0 = without P fertilizer and P_1 = 30 kg/ha P_2O_5) and 10 released haricot varieties (Tabor, AFR-702, Awash-1, Nasir, Awash melkasa, SARI-1, Omo-95, Dimtu, Awassa dume and Ibado). The treatments were arranged in a split plot design where P levels as main plot and haricot bean varieties as sub plots replicated three times. Beans were hand planted following planting times of respective locations and onset of rainfall. Each plot was 2 m wide and 3 m long. Inter and intra row spacing used were 40 and 10 cm, respectively. Source fertilizer for P_2O_5 was di ammonium phosphate (DAP) and applied at planting. The amount of N present in DAP was converted to urea and applied to P_0 plots. Two seeds were placed per hill and after emergence seedlings were thinned to maintain the desired plant density per plot. Weeding and cultivation were carried out as desired during growing season.

Measurements and analysis

Plant parameters recorded were plant height, pods per plant, seeds per pod, thousand seed weight (TSW), biomass, grain yield and harvest index (HI). Plant height, pods per plant and seeds per pod were taken from 5 randomly selected plants per plot. Grain yield was harvested from central rows by avoiding border effects and converted to kg/ha after adjusting the moisture content at 10%. Biomass was determined as the sum of straw weighed and total grain yield. Data were combined over seasons after carrying out `the homogeneity test of variances as suggested by Gomez and Gomez (1984) and were subjected to analysis of variance using the general linear model SAS version 9.1 (SAS Inst., 2003). Treatments means were compared using the least significant difference (LSD) at 5% level of significance.

RESULTS

Plant height and number of pods per plant

The data for plant height and number of pods per plant as affected by P fertilizer, varieties and their interactions are depicted in Table 1. Analysis of variance revealed that application of P fertilizer had significant effect on plant height only at Inseno over seasons. Plots applied with P fertilizer exhibited higher plant heights as compared to plots of non P applications. Conversely, P fertilizer did not have significant effect on plant height at Amaro. Significant differences were

Table 1. Effect of P fertilizer and varieties on plant height and pods/plant

P fertilizer	variety	Plant height (cm)				Pods/plant			
		2013		2014		2013		2014	
		Amaro	Inseno	Amaro	Inseno	Amaro	Inseno	Amaro	Inseno
Po	Tabor	81^{e-i}	68^{ab}	109^{a-d}	72^{a-d}	7.7^{e}	11.3^{ef}	13.0^{f}	14.0^{a-d}
	AFR-702	109^{a}	51^{b-d}	128^{a}	44^{gh}	12.3^{a-d}	15.7^{b-f}	23.0^{b-d}	16.0^{b-e}
	Awash-1	91^{b-g}	55^{b-d}	106^{a-e}	53^{e-h}	13.3^{a-c}	22.7^{ab}	31.0^{a}	21.0^{ab}
	Nasir	97^{a-d}	57^{b-d}	118^{a-d}	60^{c-g}	15.0^{a}	17.0^{a-f}	18.0^{c-f}	16.3^{b-e}
	Awashmelkasa	84^{d-i}	58^{b-d}	96^{b-e}	50^{e-h}	14.0^{ab}	22.7^{ab}	22.0^{b-f}	16.7^{b-e}
	SARI-1	86^{c-h}	47^{cd}	90^{d-f}	44^{gh}	12.3^{a-d}	17.7^{a-f}	20.0^{c-f}	16.0^{b-e}
	Omo-95	102^{ab}	61^{bc}	109^{a-d}	57^{d-h}	14.0^{a-d}	18.3^{a-e}	16.3^{d-f}	15.3^{b-e}
	Dimtu	86^{c-h}	56^{b-d}	89^{d-f}	73^{a-d}	10.3^{c-e}	14.7^{c-f}	22.3^{b-e}	12.0^{de}
	Awassa dume	71^{h-j}	50^{b-d}	89^{d-f}	47^{f-h}	14.3^{c-e}	17.0^{a-f}	19.3^{c-f}	18.0^{b-d}
	Ibado	69^{ij}	40^{d}	67^{fg}	39^{h}	11.0^{b-e}	11.0^{f}	13.7^{ef}	10.0^{e}
P1	Tabor	101^{a-c}	82^{a}	97^{b-e}`	80^{a}	8.0^{e}	21.3^{a-d}	15.0^{d-f}	12.7^{c-e}
	AFR-702	101^{a-c}	64^{a-c}	123^{ab}	79^{ab}	9.3^{de}	17.3^{a-f}	13.3^{f}	19.3^{a-c}
	Awash-1	61^{j}	64^{a-c}	58^{g}	65^{a-f}	9.3^{de}	23.7^{a}	20.7^{c-f}	26.3^{a}
	Nasir	95^{a-e}	57^{b-d}	97^{b-e}	76^{a-c}	15.3^{a}	18.7^{a-d}	33.7^{a}	22.0^{ab}
	Awashmelkasa	78^{f-i}	65^{a-c}	115^{a-d}	67^{a-e}	9.7^{de}	23.8^{a}	20.7^{c-f}	18.7^{b-d}
	SARI-1	71^{h-j}	49^{b-d}	93^{c-f}	57^{d-g}	9.0^{de}	17.7^{a-f}	23.0^{b-d}	21.7^{ab}
	Omo-95	95^{a-e}	63^{a-c}	94^{b-f}	62^{b-g}	12.0^{a-d}	21.7^{a-c}	27.0^{a-c}	12.7^{c-e}
	Dimtu	93^{a-f}	69^{ab}	122^{a-c}	63^{a-f}	9.7^{de}	19.0^{a-d}	18.0^{c-f}	13.3^{c-e}
	Awassa dume	77^{g-j}	60^{b-d}	79^{e-g}	63^{a-f}	14.3^{ab}	19.7^{a-d}	22.0^{b-f}	22.3^{ab}
	Ibado	72^{h-j}	53^{b-d}	95^{b-f}	63^{a-f}	9.7^{de}	14.0^{d-f}	20.7^{c-f}	13.7^{c-e}
	LSD	15	20	29	18	3.6	6.2	9.0	7.1
	SE±	5.55	7.13	10.22	6.31	1.28	2.58	3.2	2.48
P mean	Po	88	54^{b}	100	54	12.4	16.8^{b}	20.3	15.8^{b}
	P1	84	63^{a}	97	68	10.6	19.7^{a}	20.9	18.0^{a}
	LSD	NS	6	NS	10	NS	2.3	NS	3
	SE±	1.75	2.25	3.23	1.9	0.40	0.81	1.0	0.78
Variety mean	Tabor	91b^{c}	70^{a}	84^{cd}	69^{a}	7.8^{e}	16.2^{bc}	14.0^{d}	13.3^{c}
	AFR-702	105^{a}	57^{b-d}	121^{a}	61^{a-c}	10.8^{cd}	16.5^{bc}	18^{b-d}	17.7^{a-c}
	Awash-1	76^{d}	60^{a-c}	101^{a-d}	58^{a-c}	11.3^{cd}	23.4^{a}	25^{ab}	21.7^{a}
	Nasir	96^{ab}	57^{b-d}	102^{a-c}	68^{ab}	15.2^{a}	17.8^{bc}	27^{a}	21.3^{a}
	Awashmelkasa	81^{cd}	67^{ab}	106^{ab}	65^{ab}	11.8^{b-d}	23.2^{a}	21^{a-c}	17.7^{a-c}
	SARI-1	78^{d}	48^{cd}	92^{b-d}	52^{c}	10.7^{cd}	17.7^{bc}	22^{a-c}	18.8^{ab}
	Omo-95	98^{ab}	62^{ab}	112^{ab}	59^{a-c}	13.0^{a-c}	20.0^{ab}	22^{a-c}	18.8^{ab}
	Dimtu	89^{bc}	63^{ab}	105^{ab}	68^{a}	10.0^{de}	16.8^{bc}	20^{b-d}	13.2^{c}
	Awassa dume	74^{d}	55^{b-d}	84^{cd}	55^{bc}	14.3^{ab}	18.3^{ab}	21^{bc}	14.0b^{c}
	Ibado	71^{d}	47^{d}	81^{d}	51^{c}	10.3^{de}	12.7^{c}	17^{cd}	12.7^{c}
	LSD	11.0	12.0	20.6	12.0	2.5	5.2	6.0	5.0
	SE±	3.92	5.04	7.22	4.46	0.91	1.82	2.2	1.76
	CV (%)	11.2	21.2	17.9	18.0	19.2	24.6	26.7	25.4

Columns followed by different letters are significantly different, SD = standard deviation NS = not significant.

detected due to effect of varieties on plant heights at both locations over seasons. The highest plant height was recorded for AFR-702 at Amaro while Tabor at Inseno in both years. The shortest plants were observed for Ibado at both locations. In line with this, interaction of P fertilizer by varieties resulted in significant differences on plant heights at both locations. Variety AFR-702 exhibited the highest plant height at Amaro with non P application whereas Tabor showed the highest plant height at Inseno with recommended application of P fertilizer. The shortest plants were seen for Awash-1 at Amaro with P applications whereas, for Ibado without P fertilizer at Inseno. Similarly, P fertilizer showed significant differences on number of pods per plant only at Insneo over seasons. Plots applied with recommended P fertilizer produced more number of pods per plant as compared to non P plots. Varieties exhibited significant effect on number of pods per plant at both locations over seasons. Nasir produced the highest number of pods per plant at Amaro while Awash-1 yielded the greatest number of pods per plant at Inseno. The number of pods per plant was lowest for Tabor at Amaro and Ibado at Inseno. Interaction of P fertilizer by varieties resulted in significant differences on number of pods per plant only at Amaro. Variety Nasir at Amaro and Awash-1 at Inseno yielded the highest number of pods per plant at recommended P application. The least number of pods per plant was seen for Tabor at Amaro and Ibado at Inseno without P fertilizer application.

Number seeds per pod and thousand seed weight

The data for number of pods per plant and thousand seed weight (TSW) as affected by P fertilizer, varieties and their interactions are presented in Table 2. Application of P fertilizer did not have significant effect on TSW. However, varieties and their interactions with P fertilizer had significant difference on TSW. The greatest TSW was recorded for Ibado followed by AFR-702 at both locations over seasons. The lowest TSW was observed for Dimtu at Amaro while Awashmelkasa at Inseno. Regarding the interactions effect, Ibado gave the highest TSW at no application of P fertilizer. On the other hand, P fertilizer, varieties and their interactions did not have significant effect on number of seeds per pod at both locations over seasons.

Biomass and grain yield

The data for biomass and grain yield as affected by P fertilizer and varieties are depicted in Table 3. Main effect of P fertilizer did not have significant effect on biomass at Amaro. In contrast, biomass was significantly affected by P fertilizer application at Inseno. Significantly higher biomass yield was recorded at recommended P applications as compared to non P plots. Analysis of variance revealed that significant differences were detected due to effect of varieties on biomass yield. In general varieties averaged over P fertilizer, yielded higher biomass at Amaro than Inseno (Table 4). The highest biomass yield was recorded for Ibado at Amaro while for Omo-95 at Inseno. The lowest biomass yield was seen for Dimtu at Amaro whereas for Tabor at Inseno. Significant differences were detected due to effect of P fertilizer with varieties interactions on biomass yield at both locations over seasons (Table 3). The highest biomass yield was recorded at Amaro for Ibado with P_o whereas Omo-95 with P_1 at Inseno. The lowest biomass yield was obtained from Dimtu with P_o at Amaro while Tabor with P_o. Grain yield was significantly affected by P fertilizer application only at Inseno. Significantly higher grain yield was recorded at recommended P applications as compared to non P plots. Varieties had significant differences on grain yield. Awassa dume gave the highest grain yield at both locations and followed by Omo-95 at Amaro and Nasir at Inseno over seasons. The lowest yield was recorded for Dimtu at Amaro and Awash-1 at inseno. In line with this, P fertilizer with varieties interactions resulted in significant differences on grain yield at both locations over seasons. The highest grain yield was recorded for Awassa dume with P_1 at Amaro which was followed by Omo-95 at similar P level. The lowest yield was observed for Dimtu at P_o level. Similarly, Awassa dume out yielded at Inseno with the same treatments as that of Amaro, followed by Nasir at P_1 level. The lowest yield was seen for Awash-1 with P_o at Inseno.

DISCUSSION

Most of agronomic traits reacted differently at two locations over seasons in response to P fertilizer, varieties and their interactions (Table 4). Varieties were significantly differed in plant height, pods/plant, biomass and grain yield. Pods/plant and grain yield were higher at Inseno whereas plant height and biomass were higher at Amaro. Nearly all agronomic traits generally exhibited superior performance in 2013 than 2012 which might be attributed to good weather conditions in 2013 (Table 4). Plant height and pods/plant (Table 2) biomass and grain yield (Table 4) significantly differed to independent effect of P fertilizer at Inseno while its effect at Amaro was not significant over seasons. Hence, the application of P fertilizer had positive effect on the traits because fertilized plots performed better as compared to unfertilized plots. This probably indicates that the inherent variations of soil difference in P content which may need further P investigation in order to optimize potential yield of bean varieties at respective sites. This might have suggested that P is one of the most essential and important nutrient element in common bean physiological functions associated with growth and development. Similar results were reported by Gebre et al. (2014) that P applied plots gave higher number of pods per plant and yield as compared to unfertilized plots.

Independent effect of varieties and their interactions resulted in significant differences on plant height and pods/plant (Table 2), TSW (Table 3), biomass and grain yield (Table 4) at two locations over seasons. Varieties Awassa dume, Nasir and Omo-95 yielded better with greatest grain yield obtained from

Table 2. Effect of P fertilizer and varieties on number of seeds per pod and TSW

P fertilizer	variety	Seeds per pod				TSW (g)			
		2013		2014		2013		2014	
		Amaro	Inseno	Amaro	Inseno	Amaro	Inseno	Amaro	Inseno
Po	Tabor	4.3	4.3	6.0	5.0	164^{e-i}	197^{d-h}	323^{e}	263^{d-f}
	AFR-702	4.0	4.7	5.0	5.0	281^{b}	364^{b}	513^{c}	439^{c}
	Awash-1	3.3	4.0	6.0	4.7	159^{f-j}	155^{gh}	255^{g}	198^{gh}
	Nasir	4.3	4.0	5.7	4.7	191^{c-e}	209de	302^{ef}	258^{d-g}
	Awashmelkasa	3.7	4.3	6.3	5.7	152^{i}	152^{h}	289^{e-g}	238^{d-h}
	SARI-1	4.7	4.3	6.3	5.0	188^{c-f}	178^{e-h}	324^{e}	235^{d-h}
	Omo-95	4.7	4.3	6.0	5.0	184^{d-g}	186^{e-h}	309^{ef}	225^{e-h}
	Dimtu	4.0	4.3	5.3	3.7	179^{d-i}	195^{d-h}	148^{h}	494^{a-c}
	Awassa dume	4.3	4.3	5.7	4.7	217^{c}	272^{c}	378^{d}	275de
	Ibado	4.3	4.3	4.0	4.7	379^{a}	468^{a}	662^{a}	536^{a}
P1	Tabor	4.3	4.3	5.7	5.0	158^{f-i}	203^{d-f}	564^{b}	506^{ab}
	AFR-702	4.7	4.3	6.0	4.3	261^{b}	239^{cd}	286^{fg}	235^{d-h}
	Awash-1	4.3	4.0	5.0	5.0	155^{g-i}	164^{e-h}	536^{bc}	498^{a-c}
	Nasir	4.7	4.0	6.0	5.0	205^{cd}	194^{e-h}	255^{g}	257^{d-g}
	Awashmelkasa	4.0	4.0	6.3	4.7	179^{d-i}	163^{h}	298^{ef}	189^{h}
	SARI-1	4.3	4.3	6.0	4.3	183^{d-h}	200^{d-f}	293^{ef}	212^{f-h}
	Omo-95	4.3	4.3	6.3	5.0	181^{d-i}	196^{d-h}	325^{e}	263^{d-f}
	Dimtu	3.7	4.0	6.0	4.7	153^{h}	182^{e-h}	148^{h}	231^{d-h}
	Awassa dume	4.3	4.7	5.7	5.0	199^{cd}	199^{d-g}	314^{ef}	446^{bc}
	Ibado	4.3	4.7	5.3	4.7	366^{a}	443^{a}	394^{d}	289^{d}
	LSD	NS	NS	NS	NS	30	45	35	61.0
	SE±	0.34	0.27	0.34	0.3	10.7	15.81	12.3	21.6
P mean	Po	4.2	4.3	5.6	4.8	209	218	350	313
	P1	4.3	4.3	5.8	4.8	204	238	341	316
	LSD	NS	NS	NS	NS	NS	NS	NS	NS
	SE±	0.11	0.08	0.11	0.1	3.38	5.0	3.8	6.8
Variety mean	Tabor	4.3	4.3	5.8	5.0	160^{ef}	200^{d}	399^{c}	337^{b}
	AFR-702	4.3	4.5	5.5	4.7	271^{b}	302^{b}	444^{b}	398^{a}
	Awash-1	3.8	4.0	5.5	4.8	178^{e}	159^{e}	396^{c}	348^{b}
	Nasir	4.5	4.0	5.8	4.8	197^{cd}	201^{d}	278^{ef}	223^{c}
	Awashmelkasa	3.8	4.2	6.3	5.2	152^{f}	158^{e}	294de	223^{c}
	SARI-1	4.5	4.3	6.2	4.7	185^{d}	189de	308^{d}	248^{c}
	Omo-95	4.5	4.3	6.2	5.0	183de	191^{d}	317^{d}	244^{c}
	Dimtu	3.8	4.2	5,7	4.2	157^{f}	188de	231^{g}	363^{ab}
	Awassa dume	4.3	4.5	5.7	4.8	208^{c}	236^{c}	263^{f}	360^{ab}
	Ibado	4.3	4.5	4.7c	4.7	370^{a}	455^{a}	528^{a}	399^{a}
	LSD	NS	NS	NS	NS	21	32	24.8	43.0
	SE±	0.24	0.19	0.24	0.24	7.6	11.2	8.6	15.2
	CV (%)	13.9	10.9	10.2	12.4	13.9	12.0	6.1	11.9

Columns followed by different letters are significantly different, SD = standard deviation NS = not significant.

Awassa dume due to independent effect of varieties and their interactions with P fertilizer at Amaro. Conversely, varieties

Table 3. Effect of P fertilizer and varieties on biomass and grain yield.

P fertilizer	variety	Biomass (kg/ha)				Grain yield (kg/ha)			
		2013		2014		2013		2014	
		Amaro	Inseno	Amaro	Inseno	Amaro	Inseno	Amaro	Inseno
Po	Tabor	11703^{b-f}	4323^{h}	18229^{b-f}	4844^{g}	885^{e-h}	2292^{d-g}	769^{df}	2448^{a-e}
	AFR-702	10781^{d-f}	5573^{gh}	16146^{d-f}	6094^{fg}	1510^{a-d}	2708^{a-e}	765^{ef}	1979^{b-e}
	Awash-1	13177^{b-f}	6250^{e-h}	18229^{b-f}	7813^{d-g}	833^{e-h}	979^{g}	704^{f}	521^{e}
	Nasir	14583^{b-e}	9375^{a-e}	19792^{b-e}	9896^{a-d}	1667^{a-c}	2344^{c-g}	1573^{bc}	2188^{b-e}
	Awashmelkasa	10573^{ef}	5729^{f-h}	15625^{ef}	6250^{e-g}	990^{d-h}	2031^{fg}	992^{b-f}	1510de
	SARI-1	11302^{c-f}	8854^{b-g}	16667^{c-f}	9375^{b-f}	1250^{c-g}	1979^{g}	1208^{b-d}	677de
	Omo-95	16146^{ab}	10417^{a-d}	21354^{ab}	10938^{a-d}	1563^{a-c}	2240^{e-g}	1615^{ab}	572de
	Dimtu	11042^{g}	8333^{b-g}	4687^{g}	8854^{b-f}	521^{h}	2448^{c-g}	385^{g}	1823^{c-e}
	Awassa dume	16823^{ab}	9531^{a-e}	21875^{ab}	10052^{a-d}	1979^{ab}	3021^{ab}	1794^{ab}	2292^{b-e}
	Ibado	19792^{a}	9219^{a-e}	25000^{a}	9740^{a-b}	1406^{b-f}	2760^{ab}	1015^{b-e}	573^{e}
P1	Tabor	9010^{f}	7135^{d-h}	14063^{f}	7656^{d-g}	938^{e-h}	2604^{a-c}	910^{c-f}	1823^{c-e}
	AFR-702	14427^{b-e}	11615^{ab}	19792^{b-e}	12135^{ab}	833^{f-h}	2656^{b-e}	717^{ef}	2813^{a-d}
	Awash-1	15260^{a-d}	10781^{a-c}	20313^{a-d}	6094^{a-c}	781^{gh}	2344^{c-g}	919^{c-f}	674de
	Nasir	15625^{a-c}	8698^{b-g}	20833^{a-c}	9219^{b-f}	1458^{a-e}	2813^{ab}	975^{b-f}	3281^{ab}
	Awashmelkasa	12500^{b-f}	9896^{a-d}	17708^{b-f}	10417^{a-d}	1094^{c-h}	2500^{c-f}	756^{f}	1927^{c-e}
	SARI-1	16510^{ab}	7656^{c-h}	21875^{ab}	8177^{c-g}	1094^{c-h}	2346^{c-g}	948^{b-c}	729de
	Omo-95	13698^{b-e}	12344^{a}	18750^{b-e}	12865^{a}	1927^{ab}	2604^{b-e}	1615^{ab}	1771^{c-e}
	Dimtu	14063^{b-e}	7656^{c-h}	19271^{b-e}	8177^{c-g}	781^{gh}	2552^{b-e}	910^{c-f}	3177^{bc}
	Awassa dume	12083^{c-f}	7656^{c-h}	4688^{g}	8177^{c-g}	2031^{a}	3177^{a}	2321^{a}	3802^{a}
	Ibado	14219^{b-e}	9010^{a-f}	19271^{b-e}	9531^{a-e}	1302^{c-g}	2760^{a-d}	806^{c-f}	677de
	LSD	4583	3385	4167	3125	573	469	2083	2240
	SE±	1615	1198	1615	1146	208	206	781	781
P mean	Po	12708	7760^{b}	17760	8385^{b}	1302	2396^{b}	927	1667^{b}
	P1	12760	9219^{a}	17656	9740^{a}	1198	2708^{a}	854	2083^{a}
	LSD	NS	1042	NS	1042	NS	156	NS	677
	SE±	469	365	469	365	52	52	260	208
Variety mean	Tabor	10938de	6667^{c}	16146^{cd}	7708^{b}	990^{c-e}	2656^{bc}	849^{cd}	2135^{a-c}
	AFR-702	12604^{b-e}	8594^{bc}	17708^{bc}	9115^{b}	1354^{bc}	2760^{ab}	791^{d}	2917^{ab}
	Awash-1	14219^{a-c}	7552^{bc}	19271^{a-c}	8073^{b}	885de	788^{d}	843^{cd}	625^{c}
	Nasir	15104^{ab}	9010^{a-c}	20313^{ab}	9635^{ab}	1510^{b}	2761^{ab}	1026^{b-d}	2918^{ab}
	Awashmelkasa	11563^{c-e}	7813^{bc}	16667^{c}	8333^{b}	885de	2448^{b-d}	869^{b-d}	1406^{bc}
	SARI-1	13906^{a-d}	8229^{bc}	19271^{a-c}	8750^{b}	1146^{b-d}	2188^{d}	958^{a-c}	1667^{a-c}
	Omo-95	14948^{ab}	11354^{a}	20313^{ab}	11875^{a}	1512^{b}	2396^{b-d}	1052^{b-d}	1510^{a-c}
	Dimtu	7552^{f}	7969^{bc}	11979^{e}	8490^{b}	677^{e}	2500^{b-d}	619^{e}	1302^{bc}
	Awassa dume	9479^{ef}	8594^{bc}	13542de	9115^{b}	2031^{a}	3125^{a}	2290^{a}	3021^{a}
	Ibado	17031^{a}	9115^{ab}	22396^{a}	9635^{ab}	1406^{b}	2292^{cd}	828^{cd}	1146^{c}
	LSD	3229	2083	3125	2344	427	417	456	563
	SE±	1146	833	1125	781	156	104	573	573
	CV (%)	22.0	24.4	15.9	22.4	29.7	14.7	15.8	17.3

Columns followed by different letters are significantly different, SD= standard deviation NS= not significant

Dimtu and Awash-1 were poorly performed at Amaro. On the other hand, other varieties exhibited yield unstability at Amaro

Table 4. Summary of result location by year

Location	Year	Plant height (cm)	Pods/plant	Seeds/pod	Biomass (kg/ha)	Grain yield (kg/ha)	TSW (g)
Amaro	2012	86[b]	11.5[c]	4.2	12708[b]	1250[c]	206[d]
	2013	99[a]	20.6[a]	5.7	17708[a]	1198[c]	346[a]
Inseno	2012	58[c]	18.2[b]	4.3	8489[c]	2552[a]	228[c]
	2013	61[c]	16.9[b]	4.8	9063[c]	1875[b]	314[b]
	LSD	5	1.5	NS	885	260	9
Location mean	Amaro	92[a]	16.1[b]	4.9	15208[a]	1198[b]	276
	Inseno	59[b]	17.6[a]	4.5	8802[b]	2188[a]	271
	LSD	3	1.1	NS	625	156	NS
Year mean	2012	72[b]	14.9[b]	4.3	10625[b]	1510[b]	217[b]
	2013	79[a]	18.8[a]	5.3	13385[a]	1875[a]	330[a]
	LSD	3	1.1	NS	625	156	7

Columns followed by different letters are significantly different, NS= not significant

Table 5. Correlation between selected parameters with grain yield

Parameter	Grain yield
Plant height	0.22*
Pods per plant	0.60*
Seeds per pod	0.66*
TSW	0.51*
HI	0.51*
Biomass	-0.61*

over season. At Inseno Awassa dume, Nasir and AFR-702 exhibited better grain yield with greatest grain yield which was still achieved from Awassa dume. Varieties Awash-1 and Ibado were poorly performed whereas other varieties were shown to yield unstability over seasons. Variety Awassa dume showed the most yield stability across location and over seasons. Hence, subjecting bean varieties to P fertilizer and different environment resulted in genetic variability and ability in adapting and capturing resources for growth and development. These differences for traits could be attributed to the inherent genetic variability and adaptability differences to their respective local environments. Abay and Bjornstad (2009) indicated that genotype by environment (G x E) interactions is a differential genotypic expression across environments which affect the genotypes rankings within each environment and hence relevant for identifying mega environments and targeting genotypes.

Correlation between selected parameters and yield

The correlation of major agronomic parameters with yield, irrespective of P fertilizer and varieties is depicted in Table 5. The association of plant height with yield was positively significantly (P Ò 0.05) correlated. This suggests that plant height probably contributed to yield increase by enabling a plant to bear more number of pods per plant. Similarly, number of pod per plant, seeds per pod and TSW had positively significantly associated with yield. In contrast, biomass yield was negatively significantly associated with grain yield. The multiple linear regression equation $Y = 13.16X_1$ (P levels) + $83.78X_2$ (Varieties) with $R^2 = 0.55$ was significant (P Ò 0.05) indicating that grain yield was affected by P fertilizer and haricot bean varieties.

Conclusion

P fertilizer, common bean varieties and their interactions influenced yield and yield components of the common bean. Nasir produced the highest number of pods per plant at Amaro while Awash-1 yielded the greatest number of pods per plant at Inseno. The greatest TSW was recorded for Ibado which was followed by AFR-702 at both locations. Awassa dume gave the highest yield at both locations followed by Omo-95 at Amaro and Nasir at Inseno. Based on this finding, Awassa dume and Omo-95 for Amaro and Awassa dume and Nasir for Inseno could be best choice for the respective locations.

Conflict of interest

Authors have none to declare.

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