Agronomic performance of some haricot bean varieties (*haseolus vulgaris* L.) with and without phosphorus fertilizer under irrigated and rain fed conditions in the Tigray and Afar regional states, northern Ethiopia

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ABSTRACT

Haricot bean is an important source of protein, calories and cash for small holder farmers of Ethiopia. Five genotypes of haricot bean were grown with and without phosphorous fertilizer application, under irrigation and rain fed growing conditions in randomized complete block design with three replications in three locations of the Tigray and Afar regional states, northern Ethiopia. The aim of the study was to examine the performance and select the best and well adapted varieties, as well as to determine the role of phosphorus on yield response of varieties and on root nodulation. Varieties like Awash-1 and Mexican-142 were better in terms of earliness to maturity. Variety Chore exhibits high mean grain yield (24.5 qt/ha under irrigation and 19.6 qt/ha under rainfed) followed by Awash-Melka (20.7qt/ha under irrigation and 19 qt/ha under rainfed). Phosphorus application did not significantly affect various parameters examined and its effect was erratic and inconsistent. Significant variations were observed among haricot bean varieties for number of nodules per plant. It is recommended to grow early maturing varieties Awash-1 and Mexican 142 under rain-fed and the intermediate to late maturing and better yielding varieties such as Awash-Melka and Chore under irrigation.

Keywords: Haricot bean varieties, Fertilizer-P, growing season, Northern Ethiopia.

1. INTRODUCTION

Haricot bean (*Phaseolus Vulagris* L), locally known as 'Boleqe' also known as dry bean, common bean, kidney bean and field bean is a very important legume crop grown worldwide. It is an annual crop which belongs to the family Fabaceae. It grows best in warm climate at temperature of 18 to 24^{o}C (Teshale et al., 2005). Despite the importance for nutrition and export, its cultivation in Tigray and Afar areas is limited to small areas. Potential haricot bean varieties which were released from Ethiopian Agricultural Research centers should be tested in those areas in order to expand its area of production and increased productivity.

Haricot 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). The crop is adapted to a wide range of climatic condition ranging from sea level to nearly 3000 meters above sea level (m.a.s.l.) depending on variety selection. However, it does not grow well below 600 meters due to poor pod set caused by high temperature (Dev and Gupto, 1997).

In Ethiopia, Haricot bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). The major haricot bean producing areas of Ethiopia are central, eastern and southern parts of the country (CSA, 2011). The crop grows well between 1400 and 2000m above sea level (Fikru, 2007). In 2011/12, total Haricot bean production in the country was about 3,878,023.01 quintals (1.77% of the grain production) on approximately 331,708.15 hectares of land (2.74% of the grain crop area) (CSA, 2011). The wide range of growth habits of haricot bean among varieties has enabled the crop to fit many growing situations (Kristin et al., 1997). Early maturity and moderate degree of drought tolerance led the crop's vital role in farmers' strategies for risk aversion in drought prone lowland areas of the country (Fikru, 2007). However, yield per unit area is very low especially in Tigray, northern Ethiopia which is about 8.24 qt/ha, compared to the national average of 11.67 qt/ha (CSA, 2011). This low yield is attributed to various constraints such as moisture stress, absence of improved high yielding varieties, low soil fertility, losses due to insect pests and disease (Eden, 2002; Ferris and Kaganzi, 2008; Girma, 2009). Varieties differ for their response to these constraints but are largely influenced by the environmental conditions (Wortman et al., 1995). Selection of varieties well adapted to the local agro-ecological conditions, soil fertility and moisture level could improve the productivity of Haricot bean in these areas. However, little research is done so far in this regard, despite its importance the crop has been introduced inadequately to this part of the country. Moreover, seeking for appropriate alternative N-fixing crops like haricot bean is essential to improve the soil fertility as well as increase crop production and livelihoods of farmers.

Bean productivity is greatly influenced by soil fertility especially phosphorous and nitrogen. They have high nitrogen requirement for expressing their generic potential and 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). Most soils of northern Ethiopia particularly the study areas are depleted of nutrients because of the long years repeated cultivation and poor soil fertility management practices. Farmers in the study areas cultivate cereal crops continuously year after year; moreover, crop residues and cow dung are used for fuel instead of for soil conditioning. Therefore, the aim of this study was to select the best performing and suitable variety/varieties of haricot bean for irrigated and rain-fed agriculture condition of the study areas. Furthermore it was aiming to evaluate the role of phosphorous on yield performance and on root nodulation of some haricot bean varieties.

2. MATERIALS AND METHODS

2.1. Description of the Study Areas

Field experiment was conducted in three agro-ecological zones of two regions in Northern Ethiopia, the Tigray and Afar Regional States namely in Atsbi-Wonberta (Haikmeshal) and Wukro (Dongolo) (both from the Tigray region) and at Aba'ala (Afar region) during the 2008 off season (using irrigation) and main season (under rain fed) growing conditions. All the testing sites are lowland to mid-altitude areas which have the potential for haricot bean production. They have also better water resources for irrigable crop production.

Atsbi (also known as Atsbi Endaselase) is located in the Eastern Zone of the Tigray Region. Haikimeshal is one of the villages of this zone that located about 12 km south east of Atsbi. The sites are located at a latitude and longitude of 13°52′N and 39°44′E, and 13.867°N and 39.733°E respectively with an elevation of 2630 meters above sea level (m.a.s.l). Its mean annual rain fall is 260.25 mm (BoARD 2011). Aba'ala (also known as Shiket) is a town in Afar regional state, situated at a latitude and longitude of 13°22′N and 39°45′E with an elevation of 1482 m.a.s.l. Its mean annual rain fall is 260.25 mm (BoARD, 2011).

Dengelo is a village near the vicinity of the Wukro town located in the area stretching from 13°33'-13°58' North latitude and 39°18'-39°41' East longitude with elevation ranging from 1760 to 2720 m.a.s.l. The annual average rainfall of the area ranges from 350-450mm. The annual average rainfall of the area ranges from 350-450mm.

2.2. Experimental Design and layout

Five haricot bean varieties (Awash-1, Awash-melka, Argen, Mexical-142 and Chore) and two P-fertilizer levels (0 and 46 kg P_2O_5 /ha) in a factorial combination were used as a treatments (combined in to ten treatments). The experiment was laid out in a randomized complete block design (RCBD) with three replications. All the test varieties were white seeded obtained from the Melkasa Agricultural Research Center (Nazareth). The P-level applied to plots was calculated from the rate recommended for pulse crops, which is 100 kg/ha DAP. The source of fertilizer was TSP (46% P_2O_5 or 20% P) and it was applied during planting as a top dressing. The size of the experimental plots was 3 m x 4.2m (12.6m^2) with 1.5 m spacing between blocks and 1.0 m between plots. Each plot had 7 rows. The inter-row and intra-row spacing were respectively 0.6 m and 0.2 m. The central five rows were used for data collection. All agronomic practices such as land preparation and weeding were performed as per the local farmers' practices.

2.3. Sampling and Preparation of Soil for Laboratory Analysis

For site characterization, composite (0-30cm) top soil sample were taken using a soil auger from the all the trial sites and subjected to physical and chemical analysis before planting and after harvesting. The soil samples were air dried and ground to pass through 0.2 mm sieve and analyzed for total N, available P, pH, organic carbon (OC), available K, EC, and physical properties at Mekelle University soil laboratory. Soil analysis was made as per the normal laboratory procedure. Available phosphorus in soil was estimated by Olsen extraction method (Olsen *et al*., 1954). The content of P extracted by Olsen method was determined using spectrophotometer following the procedure described by Murphy and Reliy (1968). The chemical and physical properties of the soil before planting are presented in table 1.

2.4. Data Collection and Statistical Analysis

Data on agronomic traits such as days to physiological maturity, number of pods per plant, number of seeds per pod, 1000 seed weight and grain yield were recorded. Number of root nodules per plant was also recorded at 30, 45 and 65 days after crop emergence (DAE). Data for pod/plant and number of root nodules/plant were collected from the average value of randomly selected five plants/plot. Analysis of variance was performed using Genstat and MSTAT-C software. Duncan multiple range test was computed at 5% to delineate significance difference between treatments, varieties and locations. Bartlet's test was applied for homogeneity of variance test (Steel and Torrie, 1998). Correlation coefficients were computed to assess the relationships between yield and yield components of the common bean varieties across locations.

3. RESULTS

3.1. Chemical and Physical properties of soils of the experimental sites before planting and after crop harvest

The available phosphorus of the experimental sites was higher after harvesting than before planting (Tables 1 & 2). Comparing to Landon and Booker (1991) standards, Haikimeshal and Wukro sites were P-deficient whereas Shiket had adequate Phosphorus before and after planting. Similarly, all the experimental sites were deficient in nitrogen before and after planting (Tables 1 & 2). Similarly, experimental sites vary in their organic carbon. Shiket has highest organic carbon. The pH levels of all the experimental sites were slightly higher and relatively skewed towards the alkaline state.

Table 1. Chemical and physical properties of soil (0-30 cm) of experimental sites before planting.

S.No.	***Nutrient content and textural class***	***Experimental sites (testing locations)***		
		Haikmeshal	***Shiket***	***Wukro***
1	Organic Carbon (%)	0.663	3.63	0.74
2	EC (ds/m)	0.08	0.58	0.21
3	Available P in ppm (mg/kg soil)	5.06	14.04	5.52
4	Available K in ppm (mg/kg soil)	78.53	450.76	73.36
5	Total nitrogen (%)	0.03	0.16	0.03
6	pH (paste)	7.96	8.07	8.29
7	Sand (%)	54	22.36	40
8	Silt (%)	27.64	61.28	41.64
9	Clay (%)	18.36	16.36	18.36
10	Textural classification	Sandy	Silt loam	Loam

Table 2. Chemical and physical properties of soil of experimental sites sampled after crop harvest.

S.No.	***Soil characteristics***	***Analytical & textural results for the untreated plots***			***Analytical & textural results for the treated plots***		
		H/meshal	***Shiket***	***Wukro***	***H/meshal***	***Shiket***	***Wukro***
1	Soil pH (paste)	8.44	8.11	8.56	8.36	7.99	8.48
2	Organic Carbon (%)	1.056	2.21	0.95	1.074	0.95	0.91
3	Total Nitrogen (%)	0.076	0.17	0.084	0.0812	0.084	0.0812
4	E.C (ds/m)	0.13	1.13	0.21	0.08	1.23	0.21
5	Available P in ppm (mg/kg soil)	2.16	12.26	2.66	4.28	26.5	4.6
6	Sand (%)	56.36	24.36	42.36	54.36	24.36	44.36
7	Silt (%)	29.28	41.28	39.28	29.28	40.38	39.28
8	Clay (%)	14.36	34.36	18.36	16.36	35.36	16.36
9	Textural classification	silt loam	clay loam	loam	silt loam	clay loam	loam

3.2. Agronomic performance of haricot bean varieties

3.2.1. Days to physiological maturity

Highly significant variations were observed (P<0.001) among haricot bean varieties for days to maturity both under irrigation and rainfed growing conditions. Varieties like Awash-1 and Mexican-142 were more early (90-94 days) than others whereas the variety Chore requires relatively more days (100-114 days) to reach maturity (Table 4). There was also significant variation among localities in influencing the days required to reach physiological maturity (Table 3). Most varieties required relatively shorter days to reach maturity at Shiket (87days) than the other localities. However, application of P-fertilizer did not affect maturity of the haricot bean varieties (Table 3). Relatively less number of days was required to reach maturity under irrigation than under rain-fed growing condition

Table 3. Response of haricot bean varieties with and without P-fertilizer for days to maturity under irrigated and rain-fed conditions.

Source	***Days to physiological maturity***							
	Testing locations						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	RF	IR	IR	RF	IR	RF	IR	RF
Awash 1	94.5[c]	88.0[b]	97.3[cd]	94.2[b]	86.00[c]	NA	94.4[c]	94.33[c]
Awash Melka	1o6.2[b]	98.0[a]	102.0[b]	110.8a	99.17b	NA	96.39b	108.5[b]
Argen	104.5[b]	92.2[b]	98.0[c]	107.3a	106.50a	NA	92.22c	105.9[b]
Mexican-142	96.3[c]	88.0[b]	94.0[d]	92.5b	86.67c	NA	89.56c	94.42[c]
Chore	113.7[a]	101[a]	106.0[a]	114.3[a]	113.50[a]	NA	100.3[a]	114.0[a]
Significance level	**	*	**	**	**		**	**
SE±	1.83	0.9	2.24	2.79	0.9	NA	0.914	1.66
CV (%)	4.34	4.1	3.1	6.6	4.1	NA	4.1	5.59
P1 = 46 kg P_2O_5/ha	103.5[a]	95[a]	100.6[a]	103.5[a]	88.67a	NA	94.76[a]	103.9[a]
P0 = 0 kg P_2/ha	102.5[a]	94[a]	99.4[a]	104.2[a]	85.67[a]	NA	93.02[b]	103 [a]
Significance level	NS	NS	NS	NS	NS	--	*	NS
SE±	1.15	0.57	3.16	1.77	0.57	NA	0.914	1.05
C.V%	4.34	4.1	3.1	6.6	4.1	NA	4.1	5.59

Key: *Treatments followed by similar letters are not statistically significant , * P<0.05, ** P<0.01, NS = non-significant, RF= Rain fall, IR=Irrigation,*
na= data not recorded due to early season drought crop failure.

3.2.2. Number of pods per plant

Significant differences (P<0.001) were exhibited among haricot bean varieties for number of pods per plant. Relatively more numbers of pods/plant were recorded from Chore variety with a respective 30 and 13.79 pods per plant under irrigation and rainfed growing condition. On the other hand, Awash-Melka had the lowest number of pods per plant with a respective pod number/plant of 25.4 and 10 pods under irrigation and rainfed growing conditions respectively (Table 4). Application of P-fertilizer did not affect the number of pods per plant. Generally, more number of pods per plant was recorded from the irrigated trial (25.4-29.98 pods per plant) than the rain fed growing condition (10.05-13.79 pods per plant).

Table 4. Response of haricot bean varieties with and without P-fertilizer for number of pods per plant under irrigated and rain-fed conditions.

Number of pods per plant								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	IR	RF	IR	RF	IR	RF	IR	RF
Awash 1	17.6[b]	11.3b	9.6[bc]	9.1b	57.90[a]	-na	28.337[b]	10.17[b]
Awash-Melka	14.8[b]	11.2b	9.2[c]	8.9[b]	52.20[a]	-	25.388[c]	10.05[b]
Argen	22.3[a]	14.2a	16[a]	11.5[a]	47.50[a]	-	28.61b	12.83[a]
Mexican-142	20.6[ab]	11.9b	13.7[ab]	9.5[b]	60.20[a]	-	31.489[a]	10.73b
Chore	22.2[a]	14.8a	12[abc]	12.8[a]	55.47[a]	-	29.977[a]	13.79[a]
Significance level	*	**	**	**	NS	-	*	**
SE±	2.5	0.47	4.7	0.33	4.7	-	2.5	0.28
CV (%)	38.2	9.22	3.71	7.73	17.81	-	27.8	8.7
P1 = 46 kg P_2O_5/ha	21.3a	13.1a	33.8a	10.5a	63.5a	-	38.4a	11.78 a
P0 = 0 kg P_2O_5/ha	17.8a	12.3a	32.0a	10.2a	61a	-	38.1a	11.24 b
Significance level	NS	NS	NS	NS	NS	-	NS	*
SE±	1.58	0.3	0.35	0.21	3.35	-	1.58	0.18
C.V%	38.2	9.22	3.71	7.73	17.81	-	27.8	7.8

Key: *Treatments followed by similar letters are not statistically significant, * P<0.05, ** P<0.01, NS = non-significant, RF= Rain fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure

3.2.3. Average number of seeds per pod

Haricot bean varieties were exhibited variation for number of seeds per pod. The variety Awash-Melka produces more number of seeds per pod (6.46 under irrigation and 7.43 under rain fed growing condition) compared to the other varieties. On the other hand, Mexican-142 produces the lowest number of seeds per pod about 5.69 and 5.33 seeds per pod under irrigation and rain fed condition, respectively (Table 5). As shown in the table application of P-fertilized did not show any influence on number of seeds per pod (among locations and season (irrigation and rain fed growing condition).

Table 5. Response of haricot bean varieties with and without P-fertilizer for number of seeds/ pod under irrigated and rain fed conditions.

Number of seeds per pod								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	IR	***RF***	***IR***	***RF***	***IR***	***RF***	***IR***	***RF***
Awash 1	6.2a	6.1b	5.43a	5.4b	6.856ab	-na	6.17a	5.77b
Awash-Melka	6.6a	7.3a	5.73a	7.6a	7.068a	-	6.46a	7.43a
Argen	5.9a	6.5b	5.37a	5.7b	5.975c	-	5.77b	6.00b
Mexican-142	5.9a	5.4c	5.67a	5.3b	5.638c	-	5.69b	5.33b
Chore	6.3a	6.4b	6.20a	6.1b	6.575b	-	6.36a	6.28b
Significance level	NS	**	NS	**	**	-	**	**
SE±	0.157	0.21	0.157	0.32	0.087	-	0.097	0.19
CV (%)	6.3	8.17	6.8	13.34	6.8	-	6.8	10.93
P1 = 46 kg P_2O_5/ha	6.3a	6.35a	5.77a	5.9a	5.77a	-	6.14a	6.13 a
P0 = 0 kg p_2o_5/ha	6.1a	6.34a	5.54a	6.1a	5.54a	-	6.05a	6.24 a
Significance level	NS	NS	NS	NS	NS	-	NS	NS
SE±	0.088	0.13	0.087	0.21	0.087	-	0.06	0.12
C.V%	6.3	8.17	8.91	13.34	5.61	-	6.8	10.93

Key: *Treatments followed by similar letters are not statistically significant (P<0.05), * P<0.05, ** P<0.01, NS = non-significant, RF= Rain fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure.

Table 6. Response of haricot bean varieties with and without P-fertilizer for Grain yield under irrigated and rain fed conditions.

Grain yield (qt/ha)								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	RF	***IR***	***IR***	***RF***	***IR***	***RF***	***IR***	***RF***
Awash-1	16.44c	19.8b	14.8a	16.1ab	31.1a	- na	23.0 a	16.5b
Awash-Melka	19.87a	18.81b	11.6a	18.3a	28.3a	-	20.7 ab	19.0a
Argen	18.33b	20.14b	18.0a	15.6b	20.3b	-	15.6 c	17.0b
Mexican-142	17.40bc	21.80b	17.9a	15.5b	22.5b	-	20.5 ab	16.5b
Chore	20.78a	30.10a	15.3a	18.5ab	27.0a	-	24.5 a	19.6a
Significance level	**	*	NS	*	NS	-	*	**
SE±	0.05	0.087	0.087	0.7	0.087	-	0.087	0.42
CV (%)	4.45	32.9	32.9	7.98	31.98	-	32.9	6.6
P1 = 46 kg p_2o_5/ha	19.71a	22.9	15.3a	18.1	22.8a	-	21.9 a	18.5a
P0 = 0 kg p_2o_5/ha	17.22b	21.30	15.2a	15.1	17.5b	-	21.6 a	16.0b
Significance level	**	NS	NS	**	*	-	NS	**
SE±	0.3	0.055	0.055	0.44	0.055	-	0.055	0.27

Key: *Treatments followed by similar letters are not statistically significant (P<0.05), * P<0.05, ** P<0.01, NS = non-significant, RF= Rain ; The haricot bean varieties tested had a fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure.

3.2.4. Grain yield

A significant variation was observed among haricot bean varieties in their response to gain yield. The highest yield was recorded from the variety Chore under irrigation growing condition (24.5 qt/ha) while Awash-Melka was the highest yielder under rain fed growing condition (19 qt/ha). The application of P-fertilizer had positive effect on yield because fertilized plots gave better yield compared to unfertilized plots in the rainfed growing condition (Table 6). Grain yield was generally higher under irrigation compared to rainfed growing condition.

3.2.5. Thousand Seed Weight

The haricot bean varieties tested had a significant variation among each other for thousand seed weight. Under irrigated growing condition, the variety Awash-Melka produces the highest seed weight (295.79 gm) while under rain-fed growing condition the variety Chore was the highest (298.8 gm) followed by Awash-Melka (287.8 gm). The variety Argen was the least in seed weight. There was no positive influence of P-fertilizer application on seed weight of the haricot bean varieties (Table 7).

Table 7. Response of haricot bean varieties with and without P-fertilizer for thousand seed weight under irrigated and rain fed conditions.

Source	1000 seed weight (gm)							
	Testing locations						Mean of combined analysis	
	Haikimeshal		Wukro		Shiket			
	RF	IR	IR	RF	IR	RF	IR	RF
Awash 1	281.5bc	294.5b	276.5b	267.2c	252.73a	-na	274.56b	274.3c
Awash Melka	284.5b	313.6a	314.9a	291.0ab	258.72a	-	295.79a	287.8b
Argen	274.0c	259.5d	276.4b	259.3c	250.55a	-	262.15c	266.7d
Mexican-142	283.3b	273.8cd	271.1b	284.7b	251.52a	-	265.46cb	284.0b
Chore	297.2a	278.3c	275.9b	300.5a	243.70a	-	265.98cb	298.8a
Significance level	**	**	*	**	NS	-	**	**
SE±	2.56	3.2	3.2	4.5	3.2	-	3.2	2.6
CV (%)	2.69	7.9	7.9	4.84	8.48	-	7.9	3.9
P1 = 46 kg p_2o_5/ha	286.9 a	286.4a	283.6a	282.2a	254.6a	-	274.9a	284.6a
P0 = 0 kg p_2o_5/ha	281.2 b	282.0a	283.8a	278.8a	248.5a	-	271.4a	280.1a
Significance level	*	NS	NS	NS	NS	-	NS	NS
SE±	1.63	2.04	2.04	2.87	2.04	-	2.04	1.7
C.V%	2.69	7.9	7.9	4.84	8.48	-	7.9	3.9

Key: *Treatments followed by similar letters are not statistically significant (P<0.05), * P<0.05, ** P<0.01, NS = non-significant RF= Rain fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure.

Table 8. Response of haricot bean varieties with and without P-fertilizer for nodulation at 30 days after emergence under irrigated and rain fed conditions.

Number of nodules/plant at 30 DAE								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	IR	***RF***	***IR***	***RF***	***IR***	***RF***	***IR***	***RF***
Awash 1	0.524a	0.17c	0.00a	0.000b	0.00	- na	0.175a	0.0883 b
Awash Melka	0.539a	1.19ab	0.24a	1.228 a	0.00	-	0.258a	1.209 a
Argen	0.524a	0.00c	0.28a	0.523b	0.00	-	0.271a	0.262 b
Mexican-142	0.000a	0.50bc	0.00a	0.000b	0.00	-	0.00a	0.250 b
Chore	1.069a	1.33a	0.47a	1.335a	0.00	-	0.513a	1.335 a
Significance level	NS	**	NS	**	NS	-	NS	**
SE±	0.14	0.25	0.14	0.21	0.14	-	0.14	0.168
CV (%)	61	46	33.7	27.3	9.4	-	61.1	27.6
P1 = 46 kg p_2o_5/ha	0.586a	0.57a	0.304a	0.701a	0.00a	-	0.297a	0.635a
P0 = 0 kg p_2o_5/ha	0.476a	0.71a	0.094a	0.534a	0.00a	-	0.190a	0.620a
Significance level	NS	NS	NS	NS	NS	-	NS	NS
SE±	0.089	0.163	0.089	0.13	0.089	-	0.089	0.106
C.V%	61	46	33.7	27.3	9.4	-	61.1	27.6

Key: *Treatments followed by similar letters are not statistically significant (P<0.05), * P<0.05, ** P<0.01, NS = non-significant RF= Rain fall, IR= Irrigation,*
na= data not recorded dueto early season drought crop failure.

Table 9. Response of haricot bean varieties with and without P-fertilizer for nodulation at 45 days after emergence under irrigated and rain fed.

Number of nodules/plant at 45 DAE								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	RF	***IR***	***IR***	***RF***	***IR***	***RF***	***RF***	***IR***
Awash 1	2.67 b	7.50a	1.833a	2.517c	1.00a	-na	4.5 c	3.44ab
Awash Melka	10.17 a	11.00a	6.50a	3.197a	0.83a	-	10.25a	6.11ab
Argen	2.50 b	5.67a	3.50a	2.813b	1.17a	-	5.25bc	3.44ab
Mexican-142	7.17 a	1.17a	1.33a	2.413c	0.33a	-	6.50b	0.94c
Chore	10.67 a	24.67a	5.00a	3.282a	1.50a	-	10.75a	10.39a
Significance level	**	NS	NS	**	NS	-	**	*
SE±	0.302	0.335	0.335	0.073	0.2	-	0.61	0.9
CV (%)	31.5	15.2	26.9	13.59	99.61	-	28.1	99.6
P1 = 46 kg p_2o_5/ha	6.73a	10.0a	3.70a	2.77a	1.72a	-	7.68 a	4.90a
P0 = 0 kg p_2o_5/ha	6.53a	9.41a	3.65a	2.17b	1.45a	-	7.21 a	4.86a
Significance level	NS	NS	NS	*	NS	-	NS	NS
SE±	0.19	0.21	0.2	0.046	0.2	-	0.38	0.3
C.V%	31.5	15.2	26.9	13.59	99.6	-	28.1	99.6

Key: *Treatments followed by similar letters are not statistically significant (P<0.05),* P<0.05, **P<0.01, NS = non-significant RF= Rain fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure.

3.2.6. Number of root nodules per plant

The tested varieties exhibited a significant variation for root nodulation. The variety Chore had the highest root nodule per plant followed by Awash-Melka both under irrigation and rain-fed growing condition. Nodule number per plant was more in the late sampling dates (45 and 65 DAE) than the early sampling dates (30 DAE) (Tables 8, 9 and 10). Nevertheless, application of P-fertilizer did not influence the number of nodules per plant. There was also significant variation among locations in terms of nodule number per plant. The least number of nodules was recorded from Shiket whereas more number of nodules per plant was recorded at Haikimeshal under irrigation and at Wukro under rain-fed growing condition. More number of root nodules was recorded under the rain-fed growing condition compared to irrigated growing condition.

Table 10. Response of haricot bean varieties with and without P-fertilizer for nodulation at 60 days after emergence under irrigated and rain fed conditions.

Number of nodules/plant at 60 DAE								
Source	***Testing locations***						***Mean of combined analysis***	
	Haikimeshal		***Wukro***		***Shiket***			
	RF	***IR***	***IR***	***RF***	***IR***	***RF***	***RF***	***IR***
Awash 1	9.00 b	1.67a	1.3a	11.2bc	1.33ab	-na	10.08b	1.44 b
Awash Melka	16.83 a	5.17a	4.5a	16.7a	0.83b	-	16.75a	3.5 a
Argen	6.50 b	3.50a	1.3a	12.5b	1.00b	-	9.5b	1.94 b
Mexican-142	9.67 b	1.17a	1.0a	10.3c	0.67b	-	10.00b	0.95 b
Chore	17.50 a	10.8a	3.8a	17.0a	2.17a	-	17.25a	5.61a
Significance level	**	NS	NS	**	*	-	**	**
SE±	0.295	0.256	0.296	0.48	0.25	-	0.89	0.256
CV (%)	22.0	195.36	96	8.73	60.5	-	24.37	31.6
P1 = 46 kg p_2o_5/ha	10.87a	4.50a	2.46a	14.3a	1.30a	-	12.83 a	1.35a
P0 = 0 kg p_2o_5/ha	12.93a	4.46a	2.20a	12.7b	0.89a	-	12.60 a	1.05a
Significance level	NS	NS	NS	**	NS	-	NS	NS
SE±	0.187	0.16	0.16	0.31	0.16	-	0.56	0.16
C.V%	22.0	195.36	96	8.73	60.5	-	24.37	31.6

Key: *Treatments followed by similar letters are not statistically significant (P<0.05), * P<0.05, ** P<0.01, NS = non-significant RF= Rain fall, IR= Irrigation,*
na= data not recorded due to early season drought crop failure.

3.3. Correlation Analysis

Correlation coefficients were computed to assess the relationships between yield and yield components of the common bean varieties across locations. Plant height had highest positive correlation with number of pods per plant at Wukro and Shiket, grain yield and biomass yield at Wukro and, number of pods per plant at Shiket (See tables 1-2). Plant height had a negative correlation with number of pods per plant, days to flowering, average pod length and days to green maturity at Haikimeshal, days to flowering at Shiket and days to green maturity, thousand seed weight and nodulation at Wukro site. The plant height had also less association with number of branches at both Haikimeshal and Wukro. Number of pods per plant had highest positive correlation with grain yield at Shiket, showed less association with days to green maturity, average number of seeds per plant and thousand seed weight.

Biomass yield had highest positive correlation with grain yield, at all sites. In addition to this highest positive correlation for thousand seed weight was observed at the Shiket site. This trait had less association with nodulation at Shiket experimental site (STables 1-3).Grain yield had highest positive correlation with thousand seed weight at Shiket site. This trait has showed less positive association with nodulation at Haikimeshal. While highest negative correlation with nodulation was observed at Wukro experimental site (See tables 1-3).

4. DISCUSSION

Genotypes Mexican-142 and Awash-1 were early maturing, whereas Chore was late maturing. Mexican-142 and Awash-1 can grow well under rain-fed growing condition since these varieties required less number of days to reach maturity. Considering the irrigated growing condition, Shiket, Haik-mesahil and Wukro have the highest to the lowest potential environments for the production of haricot bean. The occurrence of severe early season drought at Shiket drastically affects the crop survival and up in crop failure in this site. Some haricot bean varieties perform well and give better yield compared to others. Chore and Awash-Melka had significantly higher yield than the other varieties. The greatest yield of these varieties could be due to their inherent genetic potential. It could be also due to better local adaptation to the Northern Ethiopia environments. The variety Argen generally performs poorly under both rainfed and irrigated growing condition. The trial sites are characterized with less moisture and low soil fertility condition, hence varieties which tolerate these stresses perform best. Successful cultivars must have good yield and other essential agronomic characters. Besides, their performance should be reliable over a wide range of environmental conditions. The basic cause of differences in stability between genotypes is a wide occurrence of genotype x environment interactions (G x E). G x E is a differential genotypic expression across environments (Abay and Bjornstad, 2009). The genotype and the interaction sources affect genotype rankings within each environment and hence relevant for identifying mega environments and targeting genotypes. In such condition identifying single highly stable genotype associated with high yield across all environments is difficult. Soil moisture and nutrition are important factors for the varieties to fully express their genetic potential; therefore, Chore and Awash-Melka varieties could be the best choice for localities with better moisture condition or for irrigated growing condition whereas Mexican-142 and Awash-1 fits better for rain-fed growing conditions.

The results showed that phosphorus application did not significantly affect various parameters examined and its effect was sometimes erratic and inconsistent. The only parameter significantly (P=0.05) influenced by application of fertilizer-P was grain yield. The erratic and inconsistent response to fertilizer-P could be due to transformation into in soluble forms. The added phosphorus might be rendered unavailable to plants in alkaline soils due to transformation into in soluble forms (Saad et al., 2009). The most favorable pH of the soil where P is highly available to plants is in the range 5.5-7.0 (Saad et al., 2009) which is not the case in soil of the experimental area (Tables 1 and 2).

Haricot bean varieties showed great variation in their potential to produce root nodules per plant. Chore and Awash-Melka had by far more number of nodules per plant than others. These varieties are characterized by having stronger stem and better plant vigor compared to the other varieties tested. These characteristics seem contributed to have more number of nodules per plant. More nodules per plant were recorded late in the season. This might be due to increase in soil moisture level. For legumes, nodulation and N_2-fixation are dependent up on an adequate supply of both macro and micro nutrients. Poor nodulation and poor plant vigour have been observed in beans grown in soils low in P content (Kristin et al., 1997). Fertilizer P increases bean yields and causes optimum nodulation earlier during bean growth (Ssali and Keya, 1983). The overall performance of the test varieties was good in all locations except Shiket under rain fed growing condition. Therefore, it is advisable to promote haricot bean as a rotation crop in the study areas to improve the fertility level of the soil, increase source of cash for farmers and foreign currency for the country as export crop.

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