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Evaluation of some common beans (*Phaseolus vulgaris* L.) genotypes for efficiency in using phosphorus for grain yield and yield components

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ABSTRACT

Common beans (*Phaseolus vulgaris* L.) are important supplementary protein sources and soil nutrient restorer for subsistence farmers in Tanzania. Yields of common beans, however, are limited by low soil fertility, as they are grown in poor soils, often without fertilizers. Phosphorus (P) deficiency is one of the primary constraints to bean production in the tropics. Experiments were conducted at Uyole and Mbimba in Southern highlands of Tanzania to investigate the genotypic variations of common beans in P utilization based on grain yield and yield components. Eight bean genotypes were tested at 0, 30 and 60 kg P ha^{-1} as Triple Super Phosphate. A split plot in a Randomized Complete Block Design was used for arrangements of treatments. Data analysis was performed using GENSTAT statistical analysis package Discovery Edition 4. Significant differences in pods/plant, seeds per pod, 100-seed weight and grain yield among genotypes were observed. Genotype GD 4032 performed better than other genotypes at all P applications and their response to P addition was positively significant, suggesting the vital role of P in grain yield. Genotype GD 4032 could be used to improve the productivity, reduce P requirements and making bean production more sustainable.

Keywords: Phosphorus, *Phaseolus vulgaris* L., Tanzania.

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INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) is one of the most important food legumes in the world (tropical and sub-tropical regions) because of its commercial value, extensive production, consumption, socio-economic and source of carbohydrate, protein, minerals, fiber and vitamins (Singh and Muñoz, 1999). They comprise 50% of the grain legumes consumed worldwide and a balanced diet can be obtained if cereals and legumes are consumed in the ratio 2:1 (Broughton et al., 2003).

Phosphorus limitation is one of the primary constraints to bean production in Tanzania and other countries in the World. Low soil P availability is also a major nutritional constraint to nitrogen fixation in legumes. A Centro Internacional de Agriculture Tropical (CIAT) survey in Africa indicated that the major constraints to common bean production in Africa are low phosphorus availability followed by various diseases, low soil pH, and drought (Wortmann et al., 1998). Soil P-limiting conditions severely constrain bean production in Sub-Saharan Africa, resulting in an estimated loss of 356,000 t/year as might be achieved from an equivalent planted area with adequate P (Wortmann et al., 1998). Africa produces about 17% of the world's beans, with 70% of production occurring in Eastern Africa. This group ranks 8th in terms of acreage in sub-Saharan Africa. Top producers are Tanzania, Uganda and Rwanda, followed by Cameroon, Kenya and Ethiopia (FAOSTAT, 2010).

Bean yields in farmers' fields in Tanzania are still low with an average of 729 kg/ha. Common bean yield potential of 1000 kg/ha as estimated by Borton and Ashock (1984) are not realized. Yields of common beans are unfortunately limited by low soil fertility, as they are grown in poor P soils, often without fertilizer. However, common bean plants differ in their reaction to P deficiencies, some being more tolerant than others (Lynch and Beebe, 1995). Bean yields increase proportionately with an increase in P fertilization, although a maximum economic fertilizer level for bean production was found to be 47 kg P/ha in Brazil (Thung, 1991). The majority of bean producers cannot afford to correct soil fertility problem through intensive P fertilization amendment. An alternative to intensive fertilization is the selections of common bean genotypes that are more efficient in using P soils.

Bean genotypes vary substantially for efficiency of acquisition and utilization of scarce soil P for growth and grain yield (Flor and Thung, 1989). In legumes, there are differences among species in recovering non-soluble P, and genotypic differences within species (CIAT, 1995). Larger genotypic differences occur to partition-limited P to grain, thereby producing high grain yield under P-limiting conditions (CIAT, 1995). These genetic variations of common bean for efficiency in utilization of P soils in bean production are used in identification of bean genotypes capable of high yielding in low phosphorus soils. P is therefore of central importance to agricultural productivity and sustainability in both developing and high-income economies (Lynch, 1998). Thus, bean genotypes efficient in utilization of P will permit resource poor producers to climb out of the vicious cycle of low inputs and low yields. High yield stability is an important attribute of any cultivars, particularly in environments subject to several biotic and abiotic stress factors.

The objective of this study was to: (i) investigate the relative yield performance of common bean genotypes for low soil fertility at different phosphorus levels of application, and (ii) examine the interactive effect of genotype x phosphorus fertilization on the common bean yields and yield components.

MATERIALS AND METHODS

Field experiments were conducted at ARI Uyole and TaCri Mbimba Research Institutes in the Southern Highlands of Tanzania (SHT) 2015/16 season. The geographical position of Uyole is 8^0 53'S and $33^0$39'E, while that of Mbimba is 8° 6′ S and 32° 5′ E. The altitudes of Mbimba and Uyole are 1500 and 1770 m above sea level respectively. The sites chosen were representative of the main common bean growing areas in the (SHT). These areas receive a mean rainfall of between 1000 and 1600 mm annually.

Surface (0 to 20 cm) soil samples were taken from the trial sites by opening mini-pits of about 30 cm deep, air-dried ground using Tetorcyclotec-grinding machine and sieved through a 2 mm sieve prior to analysis. Soil pH for both Mbimba and Uyole was found to be medium acidic with values of 5.91 at Mbimba and 6.83 at Uyole. Total nitrogen was found to be low 0.14% at Uyole and 0.154% at Mbimba as determined by the Micro-Kjeldahl digestion distillation method (Bremner and Mulvaney, 1996). Phosphate in the extract was determined by the procedures adopted by Murphy and Riley (1963) and modified by Wotanabe and Olsen (1965). The level of P soils as low on both sites with the values of 5.69 $mgkg^{-1}$ at Uyole and 3.23 $mgkg^{-1}$ at Mbimba.

The soil textures of the experimental soils used were clay and clay loam for Mbimba and Uyole respectively. Low total N is attributed to medium organic carbon, implying small additions of organic matter and relatively high decomposition rate. Both sites were previously cropped with common bean after which it was left fallow for three seasons prior to being used for this experiment.

The experiments were laid out in split plot treatment combination in a Randomized Complete Block Design (RCBD) with three replications. The experiment was planted 20^{th} February 2016 and harvested July 13^{th}, 2016. Main factor were P levels viz. 0, 30 and 60 kg P/ha and the sub-factor were eight common bean genotypes having Indeterminate upright bush (ECAB 0623, VTTT 920-16-1, VTT 915-12-1 and Uyole 98 (control) genotypes), Indeterminate prostate (NR 126-32-12, KS 55-1-1 genotypes) and Indeterminate strong climbers (KAB 0638, GD 4032 genotypes). The plot size was 4.0 m by 2.0 m. The spacing between and within rows was 0.5 m and 0.1 m, respectively. Phosphorus, at a rate of 0, 30 and 60 kg P ha^{-1} as Triple Super-Phosphate (46% P_2O_5) characterized by rapid (moderately water-soluble) release of P and nitrogen fertilizer at a rate of 30 kg N ha^{-1} as Calcium Ammonium Nitrate (27% N) as a high quality nitrogen fertilizer were applied to the seed furrows and roughly mixed. The plot area of 2 m^2 was harvested for grain yield.

Data collection

Two centre rows (2 m^2) were used for data collection. Number of days to 50% flowering was recorded by going through all plots every day while counting number of plants which had first flower and then the days from the date of sowing was calculated and recorded. Number of days 85% physiological maturity was recorded 10 weeks after planting by counting the number of plants, which had the pods lost its pigmentation and started to dry. Number of plants harvested was recorded by counting the harvested plants per plot. Number pods per plant were recorded from 10 harvested plants counted and the average was recorded. Number of seeds per pod was recorded from 10 randomly selected from each plot were threshed separately and the total number of seeds was determined leading to the calculation of the average number of seeds per pod. 100 seed weight per plot was sampled from each plot and weighed to give the seed size. Grain from the harvested area were weighed and converted into $kgha^{-1}$

Data analysis

Data were subjected to analysis of variance (ANOVA) for the Split Plot analyses were done using GENSTAT statistical analysis package Discovery edition 4. Means of the significant treatments were separated using the least significant difference (LSD) at 5% level.

RESULTS

Effect of p application on the common bean genotypes

The ANOVA identified significant ($P \leq 0.05$) effects of genotype (G) and phosphorus (P) on yield and yield components. Based on combined analysis, the effect of locations (L) and G was significant for grain yield, pods/plant and 100 seed weight. P was significant for grain yield and 100 seed weight only. L × P interaction was significant for 100 seed weight and L × G interaction was significant for grain yield, pods per plant and 100 seed weight. Also P × G interaction was significant for grain yield.

Developmental characteristics of bean genotypes

The results showed that there were significant (P ≤ 0.05) differences for the number of days to 50% flowering among the genotypes in Uyole. However, P application did not influence days to 50% flowering (Table 1). Days to 50% flowering ranged from 39.33 (VTTT 920-16-1 at 60 kg P/ha) to 47.00 days (GD 4032 at 30 kg P/ha). Significant (P ≤ 0.05) differences for days to 85% physiological maturity between genotypes were observed among genotypes at different levels of P application (Table 1). When 60 kg P/ha was applied, plants had significantly higher number of days to 85% physiological maturity while in none P application lower number of days to 85% physiological maturity were recorded.

There were significant differences (P ≤ 0.05) among the bean genotypes on days to 50% flowering (Table 2). However P application did not influence day to 50% flowering. Days to 50% flowering ranged from 38.67 to 46.67 day across P fertilizer rates. Significant (P ≤ 0.05) differences for days to 85% physiological maturity were observed among the genotypes. Generally, days to 85% physiological maturity ranged from 84.11 to 91.45 days at all P levels. P application did not show any effect to days to 85% maturity (P ≤ 0.05). The genotype NR 126-32-12 matured earliest while KAB 0638 was the latest to mature.

Table 1. Plant developmental characteristics in beans at Uyole.

Genotypes /P kg ha^{-1}	Days to 50% flowering				Days to 85% physiological maturity			
	0	30	60	Mean	0	30	60	Mean
ECAB 0623	45.00	44.67	44.33	44.67	85.33	88.33	95.33	89.66
NR 126-32-12	42.00	40.67	43.33	42.00	85.33	86.33	90.00	87.22
VTTT 920-16-1	42.33	42.33	39.33	41.33	83.33	93.00	92.00	89.44
KS 55-1-1	44.33	44.33	43.00	43.89	83.00	90.67	91.00	88.22
VTT 915-12-1	43.33	41.00	42.33	42.22	86.00	86.33	90.00	87.44
KAB 0638	45.33	45.33	45.00	45.22	93.00	92.33	95.33	93.55
GD 4032	46.67	47.00	45.33	46.33	90.00	94.00	93.00	92.33
Uyole 98 (control)	44.00	42.67	45.67	44.11	86.33	90.00	93.00	89.78
Treatments overall mean	44.12	43.50	43.54	43.72	86.54	90.13	92.42	89.708
CV (%)	5.27				3.29			
SE (±)	0.768				1.208			

Grain yield and yield components of eight common bean genotypes

Locations differed significantly from each other on seed yield this observation was occurred due to Location × Genotypes and Phosphorus × Genotypes interaction where, Uyole yielded the higher seed weight, number of seeds/pod and 100 seed weight. Significant difference was observed for number of pod/plant where, Mbimba had higher number of pod/plant (Table 3).

Grain yield increased with increase in P application and yield ranged between 2970 kg/ha (NR 126-32-12) to 6323 kg/ha (GD 4032) shown in Table 4. Genotypes were significantly different on number of pods per plant (P ≤ 0.05). However, P fertilizer had no significant effect on number of pods per plant, number of seeds per pod and 100 seed weight. The genotype GD 4032 recorded the highest mean pods/plant while NR 126-32-12 recorded the lowest number of seeds/pod (Table 5).

The 100 seed weight was significantly (P ≤ 0.05) different among the studied bean genotypes (Table 5). When zero P was applied, genotype Uyole 98 recorded the lowest 100 seed weight, while the highest seed weight was recorded on GD 4032. At 30 kg P/ha, genotype GD 4032 produced the highest 100 seed weight and KS 55-1-1 recorded the lowest 100-seed weight.

Effect of genotype and location on grain yield and components at Uyole and Mbimba

There were significant (P ≤ 0.05) differences of the studied variables from different locations (Table 6). At Uyole all genotypes recorded the higher grain yield. Genotype GD 4032 had the highest grain yield at Uyole followed by KAB 0638. At Mbimba GD 4032 recorded the highest grain yield followed by Uyole 98 (Table 6).

Table 2. Plant developmental characteristics in beans at Mbimba.

Genotypes/ kg P/ha	Days to 50% flowering				Days to 85% physiological maturity			
	0	30	60	Mean	0	30	60	Mean
ECAB 0623	46.67	46.00	46.00	46.22	84.33	85.67	89.67	86.56
NR 126-32-12	40.00	40.33	39.00	39.78	83.00	84.33	85.00	84.11
VTTT 920-16-1	38.67	36.00	39.67	38.11	82.67	87.67	85.00	85.11
KS 55-1-1	45.67	45.60	45.67	45.65	82.67	86.33	88.00	85.67
VTT 915-12-1	39.67	40.67	40.33	40.22	84.00	83.67	88.00	85.22
KAB 0638	45.67	43.67	45.00	44.78	90.67	91.00	92.67	91.45
GD 4032	45.33	44.00	44.33	44.55	88.33	90.67	91.33	90.11
Uyole 98 (control)	44.30	42.33	43.00	43.21	81.67	89.00	87.67	86.11
Treatments overall mean	43.25	42.25	42.88	42.79	85.08	87.29	88.42	86.79
CV (%)	4.73				3.09			
SE (±)	1.17				0.89			

Table 3. Effects of location on the studied variables combined over two locations.

Genotype/Location	Grain yield (kg/ha)	Pods/plant	Seeds/pod	100 seed weight (g)
Uyole	4091.79	18.39	6.90	27.00
Mbimba	3341.12	23.16	6.60	24.30
Mean	3716.46	20.77	6.74	25.67
CV%	13.66	17.57	7.67	9.98
SE±	61.14	0.44	0.05	0.28

Table 4. Effect of P application levels on grain yield of beans at Uyole.

Genotypes/kg P/ha	Grain yield (kg/ha)			
	0	30	60	Mean
ECAB 0623	3532	3853	4394	3926
NR 126-32-12	2970	3512	4386	3623
VTTT 920-16-1	3043	3461	3009	3171
KS 55-1-1	3648	3846	4695	4063
VTT 915-12-1	3124	3650	3893	3556
KAB 0638	3859	4742	5021	4541
GD 4032	5017	5913	6323	5751
Uyole 98 (control)	3484	4351	4477	4104
Treatments overall mean	3585	4166	4525	4092
CV (%)	9.80			
SE (±)	133.62			

At Uyole, GD 4032 was the genotype with the highest number of pods per plant followed by KAB 0638 while the lowest was NR 126-32-12. At Mbimba, KS 55-1-1 had the highest pods per plant followed by GD 4032, while the lowest pod number was obtained from genotype VTT 915-12-1 and NR 126-32-12 (Table 7).

For number of seeds/pod the highest seeds/pod was obtained at Uyole with GD 4032 followed by KAB 0638. The same trend was observed also at Mbimba where GD 4032 had the highest seeds/pod followed by KAB 0638 (Table 8). For the 100 seed weight the heaviest was obtained at Uyole and the least observed at Mbimba with GD 4032 and respectively (Table 9).

Genotypes differed significantly from one other on grain yield, pods/plant, seeds/pod and 100 seed weight (Table 10). Genotype GD 4032 produced the highest grain yield, pods/plant, seeds/pod and 100 seed weight. VTTT 920-16-1 produced the lowest grain yield. NR 126-32-12 recorded the lowest number of pods/plant. The lowest 100 seed weight was observed on genotype ECAB 0623

Table 5. Effect of P application levels on yield components of beans at Uyole.

Genotypes/	Number of pods/plant				Number of seeds/pod				100 seed weight (g)			
kg P/ha	0	30	60	Mean	0	30	60	Mean	0	30	60	Mean
ECAB 0623	20.27	21.17	22.70	21.38	6.60	6.83	6.63	6.69	24.93	24.97	24.37	24.76
NR 126-32-12	20.73	18.10	23.40	20.74	6.50	6.76	6.70	6.65	30.20	27.17	27.83	28.40
VTTT 920-16-1	22.43	19.53	20.57	20.84	6.26	6.96	6.73	6.65	26.97	26.63	26.40	26.67
KS 55-1-1	21.53	22.83	22.13	22.16	6.66	6.36	6.33	6.45	23.53	23.20	24.00	23.58
VTT 915-12-1	18.97	22.17	22.40	21.18	6.56	6.96	6.90	6.81	28.87	27.27	27.37	27.84
KAB 0638	27.27	28.13	34.13	29.84	6.76	7.30	7.30	7.12	28.33	28.80	28.33	28.49
GD 4032	27.43	30.43	34.50	30.79	7.93	8.13	8.03	8.03	31.20	33.47	30.87	31.85
Uyole 98	22.03	21.87	23.60	22.50	6.63	6.70	6.66	6.66	24.47	24.63	23.90	24.33
Treatments overall mean	22.58	23.02	25.42	23.68	6.74	7.00	6.91	6.88	27.31	27.02	26.63	26.98
CV (%)	15.95				6.50				6.08			
SE (±)	1.26				0.15				0.55			

Table 6. Main effects of genotype × location for grain yields.

Variety/ Location	ECAB 0623	NR 126-32-12	VTTT 920-16-1	KS 55-1-1	VTT 915-12-1	KAB 0638	GD 4032	Uyole 98	Mean
Uyole	3926.3	3622.7	3171.1	4063.2	3555.8	4540.6	5750.8	4103.8	3578.8
Mbimba	2977.7	3072.5	2760.2	2829.9	3258.7	3443.3	4819.0	3567.0	2895.2
Mean	3716.5								
CV%	13.7								
SE±	169.3								

Table 7. Main effects of genotype × location for pods/plant.

Variety/ Location	ECAB 0623	NR126-32-12	VTTT 920-16-1	KS 55-1-1	VTT 915-12-1	KAB 0638	GD 4032	Uyole 98	Mean
Uyole	21.4	20.7	20.8	22.2	21.2	24.4	32.0	22.5	21.4
Mbimba	18.9	15.4	16.0	22.7	15.3	17.6	20.7	20.4	18.9
Mean	20.8								
CV%	17.6								
SE±	1.2								

(Table 10).

For combined analysis, fertilizer rate 60 kg P/ha produced the highest grain yield. The lowest grain yield was recorded when no P was applied. Pods/plant, seeds/pod and 100 seed weight was higher at 60 kg P/ha and the lowest was recorded when none of P was applied (Table 11).

There were significant (P ≤ 0.05) differences among the genotypes on the seed yield, number of pods per plant, 100 seed weight and number of grain per pod (Tables 12 and 13). Genotype GD 4032 yielded the highest without P application and genotype VTTT 920-16-1 was the poorest seed yielder. When 30 kg P/ha was applied, GD 4032 yielded higher than the rest while KS 55-1-1 was the lowest yielder. Genotype GD 4032 had the highest seed yielder when 60 kg/ha P was applied. Grain yields increased with increased P levels with genotype GD 4032 yielding consistently highest at all levels of P (Table 12).

Genotypes were significantly (P ≤ 0.05) different on pods per plant and P applications were also affected pods per plant (Table 13). Pods per plant increased with increase in P level. When P was applied at 60 kg P/ha, produced the highest pod number overall mean than when none of P was applied. Genotype GD 4032 produced the highest means of pods per plant NR126-32-12 recorded the lowest mean pods per plant. There was no significant (P ≤ 0.05) variation mean number of seeds per pod at 0, 30 and 60 kg P/ha application. Significant different (P ≤ 0.05) were observed for 100 seed weight where at 60 kg P/ha application increased the size than when no P was applied. The genotype GD 4032 produced higher mean of 100 seed weight while ECAB

Table 8. Main effects of genotype × location for seeds/pod.

Variety/ Location	ECAB 0623	NR 126-32-12	VTTT 920-16-1	KS 55-1-1	VTT 915-12-1	KAB 0638	GD 4032	Uyole 98	Mean
Uyole	6.7	6.7	6.7	6.5	6.8	7.1	8.0	6.7	6.9
Mbimba	6.9	6.6	6.7	6.4	6.2	6.5	7.2	6.2	6.6
Mean	6.7								
CV%	7.7								
SE±	0.2								

Table 9. Main effects of genotype x location for 100 seeds weight.

Variety/ Location	ECAB 0623	NR 126-32-12	VTTT 920-16-1	KS 55-1-1	VTT 915-12-1	KAB 0638	GD 4032	Uyole 98	Mean
Uyole	24.8	28.4	26.7	23.6	27.8	28.5	31.8	24.3	27.0
Mbimba	22.7	24.8	23.3	24.0	23.9	24.5	27.0	24.7	24.4
Mean	25.7								
CV%	10.0								
SE±	0.6								

Table 10. Effect of genotypes on different variables across two locations.

Genotypes	Grain yield (kg/ha)	Pods/plant	Seeds/pod	100 seeds weight (g)
ECAB 0623	3452.00	20.17	6.81	23.71
NR 126-32-12	3347.61	18.09	6.64	26.60
VTTT 920-16-1	2965.61	18.43	6.66	24.99
KS 55-1-1	3446.58	22.42	6.44	23.78
VTT 915-12-1	3407.28	18.24	6.51	25.85
KAB 0638	3991.94	21.04	6.81	26.48
GD 4032	5285.19	26.38	7.62	29.41
Uyole 98 (control)	3835.42	21.44	6.43	24.52
Mean	3716.46	20.77	6.74	25.67
CV%	13.66	17.57	7.67	9.98
SE (±)	119.70	0.86	0.17	0.60

0623 recorded the lowest mean of 100 seed weight (Table 13).

Effect of genotypes (G) × phosphorus (P) interaction for growth and grain yield in beans

There were significant effects of G and P on grain yield and yield components, but the interaction between G × P application was non-significant for most of the studied variables.

Character associations among common bean genotypes

The relationships between some of the traits on eight bean genotypes evaluated at Uyole are presented on Table 14. The results showed that the number of days to 50% flowering was positively and significantly correlated (r = 0.514) with the number of pods per plant and with grain yield (r = 0.353). The number of days to 85% physiological maturity was significantly and positively correlated with the number of seeds per pod (r = 0.273) (Table 14).

The number of days to 85% physiological maturity was highly significant and positively correlated (r = 0.554) with grain yield (Table 14). There was significant and positively correlated between number of pods per plant and grain yield (r = 0.290). The number of seeds per pod was highly significant and positively correlated with 100 seed weight (r = 0.590), and grain yield with values of r = 0.578 (Table 14). The 100 seed weight was also significant and positively correlated r = 359 with grain

Table 1. Main effects of P application for the yield variables combined over two locations.

Fertilizers (kg P/ha)	Grain yield (kg/ha)	Pods/plant	Seeds/pod	100 seed weight
0	3203.47	20.49	6.70	24.67
30	3739.16	20.62	6.80	26.00
60	4146.74	21.21	6.80	26.30
Mean	3716.46	20.77	6.74	25.67
CV%	13.66	17.57	7.67	9.98
SE±	74.89	0.53	0.06	0.34

Table 12. Effect of P application levels on grain yield in beans at Mbimba.

Genotypes/kg P/ha	Grain yield (kg/ha)			
	0	30	60	Mean
ECAB 0623	2502	3131	3575	3069
NR 126-32-12	2827	3162	3638	3209
VTTT 920-16-1	2464	3355	2687	2835
KS 55-1-1	2490	2933	3084	2836
VTT 915-12-1	2630	3357	3655	3214
KAB 0638	3569	3655	4325	3850
GD 4032	3845	4124	5428	4466
Uyole 98 (control)	2969	3540	3672	3394
Treatments overall mean	2942	3312	3769	3401
CV (%)	22.3			
SE (±)	253.2			

Table 13. Effect of P application levels on yield components at Mbimba.

Genotypes/	Number of pods/plant				Number of seeds/pod				100-seed weight (g)			
kg P/ha	0	30	60	Mean	0	30	60	Mean	0	30	60	Mean
ECAB 0623	18.17	20.67	22.65	20.50	6.66	6.56	7.56	6.93	20.33	23.63	23.97	22.64
NR 126-32-12	15.00	15.20	17.18	15.79	6.43	6.43	7.03	6.63	21.90	27.50	25.00	24.80
VTTT 920-16-1	16.13	16.30	18.28	16.90	6.70	6.66	6.67	6.68	20.00	24.40	25.57	23.32
KS 55-1-1	17.33	18.23	20.21	18.59	6.80	6.30	6.16	6.42	23.13	22.67	26.13	23.98
VTT 915-12-1	15.27	16.57	18.55	16.80	6.16	6.00	6.46	6.21	22.90	23.20	25.57	23.89
KAB 0638	22.50	23.20	22.15	22.62	6.23	6.76	6.46	6.48	23.10	24.23	26.07	24.47
GD 4032	20.17	20.30	24.48	21.65	7.36	7.26	6.96	7.19	22.40	28.77	29.73	26.97
Uyole 98 (control)	18.57	21.40	20.55	20.17	6.40	6.00	6.20	6.20	23.40	25.17	25.57	24.71
Treatments overall mean	17.80	18.90	20.50	19.13	6.59	6.50	6.69	6.596	22.15	24.95	25.95	24.35
CV (%)	19.70				8.77				13.27			
SE (±)	1.21				0.19				1.08			

yield.

The phenotypic correlations of some of the traits of common bean genotypes at Mbimba are presented on Table 15. The results showed that the number of days to 50% flowering had a significant and positive correlation (r = 0.252) with the number of plants at harvest.

Based on combined analysis, there were positive and significant correlations between flowering and plant height (r = 0.238**), number of pods/plant (r = 0.301***) and grain yield (r = 0.193*) (Table 16). Positive significant correlations were also observed between number of days to 85% physiological maturity and number of seeds/pod (r = 0.329***), 100 seed weight (r = 0.273***) and grain yield (r = 0.509***) (Table 16).

DISCUSSION

The performance of bean genotypes indicated that there was an appreciable amount of genetic diversity in the

Table 14. Phenotypic correlations between some traits in eight common bean lines at Uyole.

Variables	No. of days to 50% flowering	No. of plant at harvest	No. of days to 85% physiological maturity	No. of pods/plant	No. of seeds/ pod	100-seed weight (gm)	Grain yield (kg/ha)
No. of days to 50% flowering							
No. of plant at harvest	-0.266*						
No. of days to 85% physiological maturity	0.090 ns	-0.354**					
No of pods/plant	0.514***	-0.242*	0.142 ns				
No of seeds/ pod	0.122 ns	-0.406***	0.273*	0.043 ns			
100-seed weight (g)	-0.158 ns	-0.116 ns	0.157 ns	-0.076 ns	0.590***		
Grain yield (kg/ha)	0.353*	-0.450***	0.554***	0.290*	0.578***	0.359**	

Note: *, **, ***, ns = level of significance at 0.05, 0.01, 0.001 and not significance respectively.

Table 15. Phenotypic correlations between some traits in eight bean lines at Mbimba.

Variables	No. of days to 50% flowering	No. of plant at harvest	No. of days to 85% days to physiological maturity	Number of pods/plant	Number of seeds/ pod	100-seed weight (g)	Grain yield (kg/ha)
No. of days to 50% flowering							
No. of plant at harvest	0.252*						
No. of days to 85% physiological maturity	0.109*	-0.392**					
No. of pods/plant	0.133 ns	-0.524***	0.487***				
No.of seeds/ pod	0.084 ns	-0.204 ns	0.316*	0.127 ns			
100-seed weight (gm)	0.083 ns	-0.057 ns	0.209 ns	0.323*	0.074 ns		
Grain yield (kg/ha)	0.185 ns	-0.211*	0.306*	0.413***	0.202 ns	0.321*	

Note: *, **, ***, ns = level of significance at 0.05, 0.01, 0.001 and not significance respectively.

Table 16. Phenotypic correlations between some traits in eight bean lines at Uyole and Mbimba.

Variables	No. of days to 50% flowering	No. of plant at harvest	No. of days to 85% physiologic al maturity	No. of pods/plant	No. of Number of seeds/ pod	100-seed weight (g)	Grain yield (kg/ha)
No. of days to 50% flowering							
No. of plant at harvest	-0.195*						
No. of days to 85% physiological maturity	0.081 ns	-0.442***					
No. of pods/plant	0.301***	-0.180*	0.112				
No. of seeds/ pod	0.071 ns	-0.341***	0.329***	0.141 ns			
100-seed weight	-0.096 ns	-0.204*	0.273***	-0.008 ns	0.021 ns		
Grain yield	0.193*	-0.441 ns	0.509***	0.431***	0.429***	0.360***	

Note: *, **, ***, ns = level of significance at 0.05, 0.01, 0.001 and not significance respectively.

bean genotypes as evidenced by the significant different observed between them on various characters. Yoshida (1981) also reported that there were genetic variations among bean genotypes for days to flowering, days to physiological maturity, pods per plant, seed yield and seed size. Grain yield at both locations tended to differ significantly, among the genotypes within different P application rates. These results are similar to those observed by Bolland et al. (2001) who found out that different levels of P applied to bean genotypes influenced grain yields. The results showed significant differences among genotypes for grain yield, pod per plant, seeds per pod and 100 seed weight across locations. There were also location effects on the performance of the studied genotypes with the performance. The genotype GD 4032 was the most suitable genotype in terms of grain yield at both locations indicating that it has a wide adaptability. It is evident therefore; that farmers who have little to invest in buying farm in-puts would use genotype GD 4032 without P application and could still obtain reasonable yields of common beans. These results also suggest that GD 4032 genotype would be identified and used as cultivar/parent in future bean-breeding program.

Genotype GD 4032 had the highest yield and number of pods per plant at both locations. This indicates that pods per plant and grain yield are positively correlated. Studies by Singh et al. (1989) have also shown similar relationship between yield and its components. GD 4032 that yielded highly also had the highest number of seeds per pod both sites and at all P applications levels. These results indicate that the number of seeds per pod might be controlled more genetically than the environment. The results further indicate that GD 4032 genotype produced and maintained its size irrespective of P application and the environments within which it was grown. The results agree with those reported by Hamis and Misangu (1986) who similarly found that seed size is relatively a very stable character under normal environmental conditions.

In order to understand more on the causal effects contributing to increased yields, there was a need to study other causal effects apart from phosphorus, which contributed to increased yield. Correlations between different traits are helpful in understanding the behavior of the traits and are of value in selecting the desired traits in a breeding program. Mduruma et al. (1998) reported that phenotypic correlations are important in connection with genetic causes of correlation, and also in changes brought about by selection.

Grain yield was the most effective selection criterion for increasing yield potential. It can therefore be established that genotypes, which are efficient in using P lead to increased grain yield. These results indicate that late maturing genotypes produced many pods per plant and seeds per pod (Kweka, 2005). This explains the reason why late maturing genotypes are high yielding. Genotypes KAB 0638 and GD 4032 were identified as best performers which produced high grain yield under different P levels across locations. Genotypes KAB 0638 and GD 4032 indicated higher P utilization efficiency compared to ECAB 0623, VTTT 920-16-1, VTT 915-12-1, Uyole 98, NR 126-32-12 and KS 55-1-1.

A combined ANOVA revealed significant genotype and location differences for seed yield, pods/plant and 100 seed weight. A comparison of testing locations gives Uyole more the most favorable for bean production than Mbimba. The performances of genotypes across locations were not the same due to effects of genotypes × environment/location interactions for seed yield, pods/plant and 100 seed weight. Araujo et al. (2000) reported lack of genotypes x phosphorus interaction agreeing with the results from this experiment. This means that yield response to treatments depends on field conditions and differs systematically across fields. The 30 kg P/ha levels of application resulted in increased yield of genotypes KAB 0638 and GD 4032 and VTTT 920-16-1. Yan et al. (1995) also reported that bean genotypes tolerance to P-limiting conditions, tended to perform relatively well under sub-optimal supply of P soils. Genotypes with efficient P utilization are likely to be accepted by farmers because they will reduce the cost of production.

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