THE INFLUENCES OF PLANT DENSITY ON YIELD AND YIELD COMPONENTS OF COMMON BEANS (*PHASEOLUS VULGARIS L.*)

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Abstract

A plant density experiment for common bean (Phaseolus vulgaris L.) was carried out at Egerton University, Njoro, over 2 years. Two bean cultivars, GLP2 and GLP24, were established at various spacing treatments. The objectives of the study were (i) to investigate the combined effects of common bean cultivars and plant spacing on grain yield and yield components and (ii) to determine the most suitable plant spacing and/or population density for bean production. A randomised complete block design with three replication was used. There was significant difference (p< 0.05) on grain yield among various densities. Seed weight, number of pods/plant and number of seeds/pod decreased with increase in plant density while plant mortality rate increased with increase in plant population. GLP24 was higher yielding (p< 0.05) in all plant spacing and/or plant population densities than GLP2. There was a high negative correlation (p< 0.01) between plant mortality and yield components. There was high positive correlation (p< 0.01) between grain yield and yield components. The study indicated that plant spacing influences grain yield and yield components.

Key words: *Phaseolus vulgaris*; plant spacing; plant population density; grain yield; yields components

INTRODUCTION

Manipulation of planting densities has resulted in numerous growths and seed yield responses. However, little data is available on the response of common beans to the effects of plant density. In soybean, yield responses include both increased seed yield (Board *et al*., 1990c; Boerma and Ashley, 1982; Costal *et al*., 1980; Dominquez and Hume, 1978) and no change or decrease in yield (Costa *et al*, 1980; Doss and Thurlow, 1974; Hicks *et al*., 1969; Caviness, 1966).

Grafton *et. al*. (1988) observed that there was greater seed yield increase with higher populations in determinate cultivars of dry beans. However, Neinhuis and Singh (1985) demonstrated that indeterminate cultivars of dry beans showed a yield plateau over a wide range of densities. Non of the previously reported studies integrated the components of cultivar and plant population density in a systems approach to the common bean growth and maximisation of crop yield.

Common bean is an important grain legume in Kenya. However, specific recommendations on optimum field populations are not well documented, especially under monoculture. This is partly because common bean is usually grown as an intercrop with cereals in the main growing season (Mungai, 1986). It is worth mentioning that some parts of Kenya have a bimodal rainfall pattern that allows for two cropping seasons per year, i.e., main cropping season (April - October) and short rain growing season (October - January) with the latter being left fallow.

One potential approach to utilise this fallow period is by growing a short season crop such as grain legumes. In addition to improved food security, integration of legumes into low input cropping systems could improve sustainable productivity of soil. This benefit stems mainly from increased soil N and organic matter. The objectives of this study were (i) to investigate the combined effects of common bean cultivars and plant spacing on yield and yield components and (ii) to determine plant population density for bean production.

MATERIAL AND METHODS

Site description. Field experiments were conducted at Njoro (0^0 23'S and 35^0 35'E; elevation 2225 m) during the 2001 and 2002 short rain season. The site has a mean annual temperature of 19.1^0C. The area receives an annual average amount of rainfall of 908 mm with 60% reliability. The total rainfall during the cropping period was 875 mm and 625 mm in 2001 and 2002 respectively. The mean temperature was 18.9^0C and 19.9^0C while relative humidity was 84.7% and 82.6% in 2001 and 2002 respectively. The soil types are predominantly *mollic andosols* according to FAO/UNESCO classification.

Experimental procedures. The experimental design used was randomised complete block and replicated three times. Two bean cultivars, GLP2 (determinate bush) and GLP24 (indeterminate bush), were established at 8 plant spacing treatments (25 x 25 cm, 30 x 10 cm, 30 x 20 cm, 40 x 10 cm, 40 x 15 cm, 45 x 10 cm, 45 x 15 cm and 45 x 25 cm). GLP2 matured in about three months (84 days) while GLP24 matured in about four months (119 days). The two were choosen based on their popularity with farmers and their differences in their growth habit.

The experimental plots measured 3m x 2m, separated by a path of 1 m and were prepared using hand hoes. At planting diammonium phospate (DAP) at rate of 40 kg P_2O_4 per hectare was applied. Thinning was carried out at 2-leaf stage leaving 1 plant per hill. Data was collected from the middle three rows. The following parameters were measured from 10 randomly selected plants: plant height and number of pods/plant. A random sample of 10 pods was selected from the above composite sample to determine the number of seeds/pod. Days to 50% flowering (R6), days to 50% physiological maturity (R9), 100 grain seed weight (recorded from 100 randomly selected seeds from the bulk) and grain yield were also determined. The harvested grains were dried to 12% moisture content. The stand count was carried out at harvest and plant mortality rates were calculated as:

Percent mortality rate = (Germination stand count – harvest stand count)/Germination stand count) x 100

Data analysis. Collected data were analysed for appropriate variances according to Steel and Torrie (1980), using Mstat package. Means separation was performed using Duncan Multiple Range Test at ($p<0.05$).

RESULTS AND DISCUSSION

The results of the study indicate that bean grain yield, 100 seed weight, and number of pods per plant at different plant spacing treatments were significantly difference ($P<0.05$) for both cultivars (Table 1 & 2). However, plant height, number of seeds per pod, days to flowering and days to maturity were not significantly different ($p<0.05$) among the different planting regime for both cultivars. Grain yields increase with rise in plant population assuming a parabolic curve to the plant density, with maximum yield for both cultivars at spacing of 45 cm X 15 cm. The initial increase in yield occurred because of an increase in plants/ha and probably due to more efficient utilisation of available resources.

Closer plant spacing (30 x10 cm, 40 x 10 cm and 45 x 10 cm) had the highest plant population per unit area. However, they gave relatively lower grain yield compared to moderate (25 x 25 cm, 30 x 20 cm, 40 x 15 cm and 45 x 15 cm) and wider (45 x 25 cm) plant spacing. Yield reduction at very high population could be due to interplant competition for resources such as nutrients, water and solar radiation as manifested by high plant mortality and low number of pods per plant (Table 2). The latter was attributed to high level of pod abortion due to competition for the available resources. One advantage of closer plant spacing may include reduced soil erosion potential and weed control because of earlier canopy closure. However, further studies should investigate the performance of these planting densities under different soil and climatic conditions. Moreover, the effects of the planting densities on the crops pathosystem and insects pests deserve research attention.

The leaf expansion per plant is lower compared to the low and moderate plant populations resulting in sink limitation to photosynthesis. This was due to competition for environmental resources. This explained why there was low grain yields in high plant population compared to moderate plant populations. Low plant populations gave relatively low yields because there were rather too few plants per unit area to adequately utilise both edaphic and non-edaphic resources effectively. It is therefore, reasonable not to recommend such plant populations to the farming community.

Moderate plant populations gave relatively high grain yields. This can be attributed to optimum population and reduced interplant completion. The populations gave good canopy earlier resulting in better utilisation of solar radiation, water and nutrients. Interplant competition was low leading to vigorous plant and reduced plant mortality rate during the growing period.

Plant mortality rate increased as plant populations increased (Table 2). Taken together, on average 9.7% and 7.1% plants were lost at moderate plant populations (160,000, 167,666, 166,666, and 148,1487 plants/ha) during the growing season, for GLP2 and GLP24 respectively in 2001. In 2002, it was 19.1% and 13.4% for GLP2 and GLP24 respectively. The difference in mortality rates between 2001 and 2002 could be explained by low soil moisture experienced in 2002 due to lower rainfall received, leading to more plant stress.

Low plant mortality rates were observed at the lowest plant population (88,888 plants/ha). Nil (0.0%) and 1.3% plants were lost in 2001 for GLP2 and GLP24 respectively. In 2002, 3.2% and 2.5% plants were lost for GLP2 and GLP24 respectively. The low plant mortality at low plant population was attributed to reduced interplant competition.

Highest plant mortality rate was observed in the high plant population (333,333 plants/ha). In 2001, 29.5% and 21.8% plants were lost for GLP2 and GLP24 respectively. In 2002, 39.8% and 36.2% plants were lost for GLP2 and GLP24 respectively. The high mortality rate was attributed to severe interplant competition for available environmental resources.

The indeterminate bush bean type (GLP24) yield better in all planting densities compared to determinate bush bean type (GLP2). GLP24 stays longer in the field, about four months (119 days) compared to GLP2, which stays for about three months (84 days). In addition GLP24 was a taller cultivar with higher number of pods per plant, seeds per pod and 100 seed weight compared to GLP2 (Table 2). This may have occurred because GLP24 is a taller cultivar that has an indeterminate bush growth habit and it also takes a longer period in the field compared to GLP2, giving it a chance for more synthesis of sugars.

The primary yield components (100 seed weight, number of pod/plant and number of seeds/pod) generally decreased with increase in plant population.

The greatest number of pods/plant, number of seeds/pod and 100 seed weight in both cultivars were produced from plants at the lowest population Perhaps due to greater available space and reduced interplant competition.

Phenotypic correlations among 5 traits based on plant spacing between the 2 cultivars over the 2 seasons were carried out (Table 3 and 4). Grain yield was highly correlated ($P < 0.01$) with number of pods/plant, number of seeds/pod and 100 seed weight. Hundred seed weight was not significantly correlated with plant spacing. Plant mortality was negatively correlated with number of pods/plant, number of seeds/pod, plant pacing, 100 seed weight and grain yield. Grain yield was positively correlated with number of seeds/pod, number of pods/plant and 100 seed weight. However, it is negatively correlated to plant mortality rate and plant spacing.

In conclusion, the results from the study indicated that plant spacing and/or plant population density influences grain yield and yield components. In addition, grain yield is dependent on cultivar. GLP24 performed better, for all characters under study, compared to GLP2. Therefore, it could be recommended that farmers should grow GLP24 instead of GLP2.

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Received for publication on March 15 , 2004
Accepted for publication on November 16, 2004

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Tab. 1: Influence of plant spacing, plant population and cultivar on several agronomic characters of common beans (*Phaseolus vulgaris* L) at Egerton University in 2001 and 2002.

Treatments		**2001**						**2002**					
		Cultivar											
Spacing (cm)	Plant population (plants/ha)	***GLP2***			**GLP24**			***GLP2***			***GLP24***		
		Grain yield	100 seed weight	Plant height	Grain yield	100 seed weight	Plant height	Grain yield	100 seed weight	Plant height	Grain yield	100 seed weight	Plant height
		(kg/ha)	(grams)	(cm)	(kg/ha)	(grams)	(cm)	(kg/ha)	(grams)	(cm)	(kg/ha)	(grams)	(cm)
25 x 25[b]	160,000[b]	2974	36.2	54.9	3011	38.2	72.5	1517	32.8	49.5	1923	33.6	61.9
30 x 10[d]	333,333[d]	1997	35.6	54.5	2043	36.4	69.9	1116	30.3	48.6	1043	30.6	60.5
30 x 20[b]	167,666[b]	3044	36.0	53.2	3415	38.0	71.4	1495	31.9	46.6	1830	32.2	61.6
40 x 10[d]	250,000[d]	2157	34.9	53.2	2302	36.8	72.9	1035	30.0	46.5	1155	30.6	60.4
40 x 15[b]	166,666[b]	3213	36.7	53.3	3689	37.9	70.4	1508	32.8	47.3	2079	33.3	60.5
45 x 10[d]	222,222[d]	2080	34.4	53.5	2340	36.8	68.7	1129	29.6	46.8	1217	30.5	62.5
45 x 15[b]	148,148[b]	2857	37.0	54.1	3064	38.4	71.9	1331	33.1	50.5	1802	33.9	62.3
45 x 25[c]	88,888[c]	1295	37.7	55.2	847	38.1	71.8	961	33.7	50.3	975	34.6	62.5
$LSD_{0.05}$		369.1	3.5	2.0	684.3	2.6	5.2	236.8	1.9	5.7	311.2	2.0	2.2

[a]Means followed by the same letter are not significantly different at the 0.05 level
[b]Moderate plant spacing and/or moderate plant population
[c]Wider plant spacing and/or low plant population
[d]Closer plant spacing and/or high plant population

Tab. 2: Influence of plant spacing, plant population and cultivar on number of pods per plant, number of seeds per pod and plant mortality of common beans (*Phaseolus vulgaris* L) at Egerton University in 2001 and 2002.

Treatments		**2001**						**2002**					
Spacing (cm)	plants/ha	***Cultivar***											
		GLP2			***GLP24***			***GLP2***			***GLP24***		
		Pods/plant	Seeds/pod	Plant mortality (%)	Pods/plant	Seeds/pod	Plant mortality (%)	Pods/plant	Seeds/pod	Plant mortality (%)	Pods/plant	Seeds/pod	Plant mortality (%)
25 x 25	160,000	9.2	3.6	8.7	11.5	3.9	5.9	8.8	3.7	19.5	10.1.	3.8	15.3
30 x 10	333,333	7.3	3.3	29.5	8.0	3.5	21.8	6.7	3.1	39.8	7.6	3.3	36.2
30 x 20	167,666	8.8	3.7	14.7	10.9	3.8	10.7	8.1	3.5	27.7	9.5	3.7	20.0
40 x 10	250,000	7.9	3.5	23.6	9.0	3.4	18.0	7.2	3.1	34.9	7.9	3.4	32.54
40 x 15	166,666	9.1	3.8	9.7	11.3	3.8	7.7	8.9	3.6	18.0	10.1	3.8	13.0
45 x 10	222,222	8.0	3.5	22.1	9.7	4.0	18.3	7.4	3.2	33.6	8.0	3.4	29.6
45 x 15	148,148	10.0	3.9	5.7	13.2	4.1	4.2	9.0	3.8	11.2	11.4	3.9	5.3
45 x 25	88,888	10.1	3.9	0.0	13.3	3.9	1.3	9.2	3.9	3.2	11.7	3.9	2.5
mean		8.7	3.6		10.8	3.7		8.1	3.4		9.5	3.6	
$LSD_{0.05}$													

Tab. 3: Phenotypic correlations among 6 agronomic and morphological characters measured on GLP2 common bean cultivar over 2 growing seasons (2001/2002) at Egerton University. †

	PS	HWT	PMR	NPP	NSP
Plant spacing (PS)					
100 seed weight (HWT)	0.338				
Plant mortality rate (PMR)	-0.548	0.924**			
Number of pods/plant (NPP)	0.487	0.917**	-0.987**		
Number of seeds/pod(NSP)	0.388	0.923**	-0.975**	0.992**	
Grain yield (GY)	-0.417	0.207	-0.087	0.240	0.273

**Significant at the 0.01 levels of probability.
† Based on plot means analyses across two growing seasons (2001/2002) in Egerton University, Njoro, in short rainy season (n = 8).

Tab. 4: Phenotypic correlations among 6 agronomic and morphological characters measured on GLP24 common bean cultivar over 2 growing seasons (2001/2002) at Egerton University. †

	PS	HWT	PMR	NPP	NSP
Plant spacing (PS)					
100 seed weight (HWT)	0.313				
Plant mortality rate (PMR)	-0.500	-0.977**			
Number of pods/plant (NPP)	0.549	0.960**	-0.994**		
Number of seeds/pod(NSP)	0.417	0.984**	-0.988**	0.983**	
Grain yield (GY)	-0.344	0.296	-0.158	0.124	0.207

**Significant at the 0.01 levels of probability.
† Based on plot means analyses across two growing seasons (2001/2002) in Egerton University, Njoro, in short rainy season (n = 8).