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Response of French Bean (*Phaseolus vulgaris* L.) to Rate and Ratio of Potassium Fertilizer Application

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ABSTRAK

Kajian lapangan telah dijalankan untuk menilai kesan baja potasium, apabila digunakan pada nisbah yang berbeza sebagai baja pangkal atau permukaan terhadap pertumbuhan vegetatif, lenggai tak matang dan hasil biji benih kacang peranchis. Begitu juga kualiti biji benih untuk tujuan penanaman yang ditentukan oleh percambahan sebelum atau selepas kekurangan nilai dikawal. Kadar penggunaan baja pada kadar (100:0, 50: atau 0:100 telah ditambah semasa penanaman (pangkal) atau pada pembungaan (peringkat R 1-pembajaan permukaan). Pertumbuhan kacang perancis tidak dipengaruhi oleh potasium. Perbezaannya, pertumbuhan vegetatif dan komponen paling berhasil jelas meningkat sehingga 100 kg K_2O per hektar. Penggunaan kadar yang diberikan hanya pada penanaman (100:0) meningkatkan pertumbuhan vegetatif dibandingkan dengan bila kadar itu diasingkan. Penggunaan pada pembungaan semata-semata (0:100) mengurangkan semua parameter terukur, menentukan keperluan potasium sewaktu penanaman. Hasil lenggai tak matang yang dituai untuk tujuan penanaman sayur nyata tidak bertambah oleh dua penggunaan dalam nisbah 50:50 (pangkal: pembajaan permukaan). Kualiti biji benih ditentukan oleh percambahan sebelum dan selepas kekurangan nilai dikawal juga terlibat dan penggunaan berasingan 100 kg K_2O dalam nisbah 50:50 meningkatkan percambahan.

ABSTRACT

A field study was undertaken to evaluate the effect of potassium fertilizer, when applied in different ratios, as a basal or top dressing on vegetative growth, immature pod and seed yield of French bean as well as seed quality for planting purpose determined by germination before and after controlled deterioration. The ratios of fertilizer application at a given rate of 100:0, 50: or 0:100, were added at planting (basal) or at flowering (R1 stage - top dressing). Establishment of French bean was not affected by potassium. In contrast, vegetative growth and most yield components increased significantly with up to 100 kg K_2O per ha. Application of a given rate only at planting (100:0) enhanced vegetative growth compared with a split rate. Application at flowering alone (0:100) reduced all measured parameters, confirming the requirement of potassium at planting. Yields of immature pods harvested for vegetable purposes were not significantly increased by the two applications in the ratio of 50:50 (basal: top dressing). Seed quality determined by germination before and after controlled deterioration was also affected and split applications of 100 kg K_2O in the ratio of 50:50 increased germinability.

INTRODUCTION

Piggot (1986) illustrated a greater requirement of potassium at flowering in French bean to facilitate the heavy sink effect by developing pods and seeds, and the role of this nutrient in the translocation of photosynthates. Thus general application at planting alone can lead to deficiencies, especially when the crop is grown for seed over a long period of time (Tindall 1983; Adams *et al.* 1985). Thung (1991) suggested that potassium would become a limiting factor for successful production of French bean, due to high rates of utilization and depletion of this element. Thus a study was conducted to identify the impact of different rates of potassium application on yields of immature pods and mature seed of French bean and to determine the effects of applying selected rates either at planting (basal), at planting and flower initiation (basal and top dressing) or at flowering alone (top dressing) on growth and yields of immature pods and mature seeds. The impact of these treatments on the quality of seeds for planting material was also determined by controlled deterioration, as farmers generally cultivate this crop from seeds of previous seasons.

MATERIALS AND METHODS

The experiment was carried out at the experimental unit of the Faculty of Agriculture, University of Peradeniya, Sri Lanka (7^0N, 81^0E, 470 m above sea-level), which has a tropical south Asian monsoonal climate (Domros 1974), with a mean annual rainfall of 1700 mm spread over two seasons (the rainfall over the experimental period beginning November, 1989 was 548 mm) with a mean monthly temperature of 27.4 ± 1.24^0C, and humidity of 75.2 ± 2.32%. The daylength was 11-12 hours. The soil at the site is classified as an Alfisol, with a sandy clay loam texture. The important characteristics of the top 30 cm were as follows:- pH(1.25 H_2O) 6.54 ± 0.31, organic C (Walkley and Black) 0.66% (w/w), Total N (kjeldahl) 0.42%, exchangeable K 121 ppm and a CEC of 42.2 m eq per 100 g of soil.

Uniform seeds (germination 95.2%) of the bushy type of French bean (variety Wade) were planted in well-prepared 2×3 m seed beds, at a spacing of 20×10 cm. The crop was managed as per recommendations of the Department of Agriculture (1988) and was manually weeded on two occasions. No supplementary irrigation was required.

The fertilizer treatments adopted were equivalent to 0, 50, 100 or 150 kg K_2O per ha, supplied in the form of KCl (60% K_2O). Uniform rates of 50 kg P_2O_5 and 30 kg N were applied at planting. The selected potassium levels were applied in the following ratios at planting (basal) or at flower initiation (R1) (Fageira *et al.* 1991): (A) 100:0 (B) 50:50 and (C) 0:100. At the time of the top dressing of potassium, nitrogen equivalent to 15 kg N per ha was applied, irrespective of application of potassium, to maintain uniformity. The experiment was laid out as a randomized block design with four replicates, with fertilizer treatments randomized within the block.

Crop establishment (percentage of planted seed) was determined at 8 days after planting. Thereafter, four plants were removed from each plot at 6-day intervals up to flower initiation (R1) and dry weights determined by desiccation at 80^0C for 48 hours. These data were used to calculate relative growth rates (g/g/wk). The ratio of RGR of fertilized plants to that of the control ($0K_2O$) was computed to determine the treatment effect on vegetative growth.

At 50% flowering (growth stage R3), 30 plants within each plot were tagged to determine flower and pod numbers and seeds per pod. At the time of immature pod harvest (R7), 15 of the tagged plants were used to determine yields per plant and weight of immature pods. The other 15 plants were harvested at full maturity (R8) when most mature pods had begun to split, and seed yield per plant and 100-seed weight were obtained.

The controlled deterioration tests adopted were similar to those described by Matthews and Powell (1987) and Hampton *et al.* (1992). Thus, four replicates, each containing 40 g of seeds obtained from the different potassium treatments were soaked in deionized water to obtain a 24% seed moisture content. The quantity of water added was determined by the equation described by Hampton *et al.* (1992). Thereafter, the seed samples were sealed in aluminium foil and incubated for 72 hours at 45^{0}C. Germination of seeds before and after controlled deterioration was evaluated by counting the number of normal seedlings at 14 days after planting to a depth of 2.5 cm in sand. Statistical analysis was carried out by ANOVA and comparisons by LSD, as described by Gomez and Gomez (1981).

RESULTS AND DISCUSSION

Vegetative Growth

Rates and ratios of potassium fertilizer application had no impact on the establishment of French bean (Table 1). In contrast, the ratios of relative growth rates (RGR) illustrate the benefits of applying potassium in enhancing the development of the emerged seedling. The RGR of plants in the control (0 K_2O) plots was 0.043 ($\pm$0.002) g/g/wk, which was considered the baseline. The RGR ratio increased significantly with increasing rates of K_2O, although the increment with 150 kg K_2O was marginal over that of 100 kg K_2O. Thus 100 kg K_2O could be considered optimal for good vegetative growth of French bean under the conditions of this trial.

Application of potassium levels at planting (100:0) developed the highest RGR, while the supply of 50% of a given rate at planting depressed growth. The absence of K_2O at planting showed growth rates similar to those of the control. This clearly illustrates the requirement of potassium in the basal fertilizer, as the element influences the vegetative growth phase of the plant (Wolley *et al.* 1991). However, at higher rates of K_2O (i.e. 150 kg), application of 50% of potassium at planting does not increase the RGR ratio significantly over that of the 100:0 (basal: top dressing)

TABLE 1

Effect of rate and ratios of potassium fertilizer application on vegetative growth of French bean

Rate (kg K_20) per ha	Ratio*	Establishment (%)	RGR Ratio**	Days to Flower Initiation
0	–	76	1.0	39
50	A	87 a+	1.23 a	34 a
	B	93 a	1.08 b	37 bc
	C	95 a	1.02 c	39 c
100	A	89 a	1.42 a	31 a
	B	94 a	1.25 b	35 b
	C	96 a	0.95 c	40 c
150	A	95 a	1.46 a	30 a
	B	91 a	1.34 b	33 b
	C	95 a	1.06 c	39 c
LSD P=0.05 (Means)		5.02	0.024	2.11
Interaction		NS	*	*

* Ratio of application – A = 100:0, B = 50:50, C = 0:100 (Basal: top dressing) at planting and flowering

** RGR ratio = $\frac{\text{RGR of treatment}}{\text{RGR of control (0 } K_2O)}$ (units of RGR g/g/wk)

$^+$ In a coloumn, means within a given role of fertilizer followed by a common letter are not significantly different (p = 0.05) ratio of the same quantity. This is due to adequate supply of the element for early growth by this ratio at this rate.

Flowering

Application of potassium at ratios of 100:0 or 50:50 (basal: top dressing) reduces the time to flower initiation in French bean (Table 1), and lack of K_2O at planting delays this process, which could be attributed to the weaker growth of the plants shown by RGR ratios. Number of flowers on a plant is significantly increased by application of 50 or 100 kg K_2O at planting, due to better vegetative growth at these rates and ratios. This may be attributed to reduced photosynthetic processes and carbohydrate metabolism (Ting 1982; Fageira *et al.* 1991), which influence the initiation of the reproductive phase in plants.

Pod and Seed Numbers

A similar phenomenon is observed on pod number (Table 2), although potassium fertilizer probably does not have an impact on the process of pollination. However, flower abortion could be enhanced in conditions of potassium deficiency in legumes (Hanway and Johnson 1985), which could influence the number of pods per plant. At the lower rates of K_2O, split application (50:50 basal : top dressing) reduced number of flowers and pods per plant. This was not seen at the highest rate, due to the application of sufficient quantities at planting. At all rates, application of all potassium at flowering (0:100) reduced flower and pod number, due to poor early growth of the plant. The importance of potassium in enhancing reproductive growth in French bean (Fageira *et al.* 1991) could also have affected pod growth.

Seed number per pod (Table 2) was not influenced by the rates and ratios of potassium application, except in the control treatment where the reduction was marginal. However, pod and seed development were influenced by the rates and ratios of potassium. The absence of potassium in the basal fertilizer reduces both pod and seed weights significantly. This confirmed the importance of potassium throughout the growth of the crop.

TABLE 2

Effect of rate and ratio of potassium application on yield components of French bean

Rate (kg K_2O/ha)	Ratio*	Flowers/ Plant	Pods/Plant	Seeds/Pod (g)	Wt of Pod (g)	100-seed Wt
0	–	6.2	4.0	4.5	4.9	17.42
50	A	16.2 a+	12.5 a	5.2 a	7.1 a	23.46 a
	B	10.3 b	8.8 b	5.4 a	7.3 a	24.15 b
	C	6.5 c	4.5 c	5.0 a	5.2 b	19.15 c
100	A	24.6 a	20.6 a	5.2 a	8.6 a	25.44 a
	B	20.2 b	17.5 a	5.6 a	8.9 a	28.40 b
	C	6.9 c	4.8 b	5.1 a	6.1 b	22.16 c
150	A	26.5 a	20.5 a	5.2 a	8.7 a	26.24 a
	B	25.4 a	20.1 a	5.3 a	9.2 a	30.65 b
	C	8.5 c	5.9 b	4.9 a	6.2 b	22.68 c
LSD P = 0.05 (Means)		3.9	4.81	1.96	0.76	4.09
Interaction		*	*	NS	*	*

* Ratio of applications – A = 100:0, B = 50:50, C = 0:100 (Basal : top dressing) at planting and flowering

+ In a column, means within a given rate of fertilizer followed by a common letter are not significantly different (p = 0.05)

Pod and Seed Yields

Application of potassium only on planting also reduced pod weight marginally, and seed weight significantly as both these are important sinks and the supply of carbohydrates is influenced by potassium (Mengel and Kirby 1987). Thus, application of potassium at planting and flowering ensures an adequate supply for plant growth, thereby increasing seed weight significantly. The greater impact of spilt application on seed weight could also be attributed to the longer period taken for seed maturity, as compared with that of immature pods harvested as a vegetable. Application of low rates of potassium at planting alone may not meet the demand of the crop during seed development due to the high solubility of this element, which leads to leaching losses, especially under the rainfed conditions which prevailed during this study.

Application of potassium increased both pod and seed yield of French bean (Table 3), due to better vegetative growth and enhanced values of yield components. Although yields are further increased with 150 kg K_2O the increment between 100 and 150 kg is marginal. Thus, in this study, application of 100 kg K_2O per ha is considered the optimal rate, which corresponds to most potassium fertilizer recommendations for French bean in the humid tropics (Tindall 1983; Thung 1991).

Withholding potassium in the vegetative phase reduces both pod and seed yields significantly. This confirms the importance of potassium in basal fertilizers for French bean, as for other legumes (Hanway and Johnson 1985). However, immature pod yields are not significantly increased by applying potassium at planting and flowering, especially at 100 or 150 kg K_2O per ha. At 50 kg K_2O per ha, there is a significant increment in pod yield when all of the potassium is applied as a basal dressing. This could be attributed to the influence of potassium on the vegetative growth, as a split application of 50 kg K_2O may not provide adequate quantities for optimal growth rates (Table 1). Thus farmers growing this crop for vegetative purposes can obtain high yields with one application of potassium at planting.

TABLE 3

Effect of rate and ratio of potassium fertilizer application on fresh pod and seed yield of french beans

Rate (kg K_2O/ha)	Ratio*	Pod Yield+ (g/plant)	Seed Yield** (g/plant)
0	–	20.4	4.82
50	A	69.6	14.46
	B	66.5	15.84
	C	28.6	4.96
100	A	138.1	23.57
	B	146.6	27.94
	C	38.4	6.95
150	A	153.7	25.82
	B	159.9	31.95
	C	68.3	9.96
LSD ($P = 0.05$) within a rate of K_2O		9.45	2.61
Means of rates		1.96	0.96
Interaction		*	*

* Ratio of applications – A = 100:0, B = 50:50, C = 0:100 (Basal : top dressing) at planting and flowering
\+ Pod yield determined by the harvest of fresh immature pods for vegetable purposes
** Seed yield corrected to 20% moisture at harvest

Application of potassium only at planting reduced seed yield significantly. Thus split applications are required, except at the lowest rate (50 kg K_2O per ha). In contrast to pod production, optimal seed yields are obtained by split applications, although most farmers cultivating this crop apply fertilizers once at planting (Thung 1991). The longer period of growth required for seed production needs a split applications of this soluble nutrient. The study also illustrates that applications of 100 kg K_2O as a split application provides similar yields to those of applying 150 kg K_2O at planting. Thus, judicious applications of potassium also reduces the quantity required.

Seed Quality

Potassium fertilizer influences seed quality of French bean due to its role in plant metabolism (Fageira *et al.* 1991). Thus seed germination is increased significantly by the addition of 100 kg K_2O, irrespective of the ratio of the application (Table 4), as are pod and seed yields, for which this is the optimal rate (Table 3). As for seed yields, application of potassium at flowering reduces germination, both before and after controlled deterioration. Thus, for optimal seed quality, potassium is required from planting. A comparison of germination values again indicates the importance of split applications of potassium in increasing seed quality for planting purposes, as measured by germination before and after controlled deterioration. The patterns of germination due to potassium are not altered by controlled deterioration. This is clearly evident at 100 and 150 kg K_2O, while the effect at 50 kg K_2O is marginal. This illustrates that potassium is required at both the vegetative and reproductive phases for high yields of good quality seed, which can be used for immediate consumption or planting at a later season, the latter being more important in the developing world of Asia.

TABLE 4

Effect of rate and ratio of application of potassium fertilizer on germination pattern of French bean after controlled deterioration

Rate of K_2O (kg/ha)	Ratio*	Germination (%) before cd	Germination (%) after 72 hrs cd
0	–	42	18
50	A	57	31
	B	59	39
	C	47	24
100	A	74	52
	B	91	72
	C	51	31
150	A	81	54
	B	94	67
	C	53	36
LSD (P = 0.05) Within a rate of K_2O		6.01	4.90
Means of rates		3.84	2.37
Interaction		*	*

* Ratio of applications - A = 100:0, B = 50:50, C = 0:100 (Basal : top dressing) at planting and flowering

\+ Germination determined by number of emerged normal seedlongs in 7 days

CONCLUSIONS

Potassium is a prerequisite for optimal yields of legumes, including French bean as this field study clearly illustrates. Both rates and ratios of potassium application influence vegetative growth, pod and seed yields and the quality of seeds, measured in terms of germinability. Farmers producing immature pods for vegetable purposes should apply potassium at planting to obtain high yields. In contrast, for the production of high seed yields (for both consumption and planting) applications at planting and at flowering are required. This will ensure good seed quality determined by controlled deterioration, for planting purposes. Split applications can reduce the requirement of fertilizer potassium.

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