EFFECT OF FERTILIZER LEVELS AND SPACINGS ON FRENCH BEAN GENOTYPES

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF FERTILIZER LEVELS AND SPACINGS ON FRENCH BEAN GENOTYPES"** submitted by **Mr. RAMAKRISHNA, K.**, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE) IN HORTICULTURE**, to the University of Agricultural Sciences, GKVK, Bangalore, is a record of research work done by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is a dwarf type and early yielder. It is also called as snap bean, haricat bean, kidney bean and navy bean, is one of the important leguminous vegetable. It belongs to the family leguminosae, sub family papillionaceae. South Mexico and Central America are considered to be the primarily centre of origin, while Peruvian-Ecuadorian-Bolivian region to be the secondary centre.

It is grown for the tender pods, shelled green beans and dry beans. The tender pod and dry seeds are very nutritious and is a rich source of protein, calcium, iron and vitamins. It is essentially a cool season crop in the plains and a summer crop in the hills. In places with moderate rainfall and mild summer as in some part of Deccan plataeu, it is grown round the year. It is generally sown from June to August in South India and in February in North India.

In India, french bean is cultivated extensively in the states of Karnataka, Tamil Nadu, UttarPradesh and Andhra Pradhesh. In Karnataka, it is grown in an area of 17504 ha with a production of 393840 tonnes (Anon, 1997).

French bean as legume, have certain unique features which altogether make them indispensable if not difficult to replace. Firstly, french bean play an important role in the agricultural economy of India by virtue of its ability to fix atmospheric nitrogen in symbiotic association with rhizobium and contributing sustainability to the enrichment of the soil.

The second unique feature of french bean is their deep penetrating root system which enable them to utilise the limited available moisture efficiently and contributing substantially to the loosening of soil. Because of this famers have choosen to grow under highly diversified conditions. In general, they are more drought resistant.

Thirdly, french bean has played a very important role in human diet in our country, mainly as a source of protein. Because of their high protein which varies from 20 to 30 per cent and helps in eradicating protein malnutrition, especially among children and nursing mothers.

The growth and yield depends on soil type, nutrition, plant density, cropping system, moisture supply etc. It requires a well drained and aerated soil. While some cultivars sensitive to acidic and alkaline conditions, other are quite tolerant to these adverse conditions. However, water logging is found to be detrimental for its growth and development.

It has been well established that growth and yield of french bean is mainly influenced by fertilizer availability and plant population. Within the short time of plant growth, soil alone cannot meet the entire nitrogen requirement of crop. In soils, otherwise rich in organic matter, nitrogen may not be released at a rate required to maintain rapid activities of the growth processes. In practice, therefore nitrogen has to be made available to the plant in the form of nitrogenous fertilizer to get early growth and higher yield. Phosphorus is an essential element for plant growth . It hastens the maturity of the crop, increases yield and improves the crop quality. Potassium is often described as a 'quality element' for crop production. It helps in better utilisation of nitrogen and increases protein formation.

Proper spacing is necessary for field grown vegetables. If plants are planted too far apart, space is not utilized efficiently and yield per unit is low. If plants are planted too densely, however shade each other compete for nutrients, water and light causing low yields. Hence it is essential to find the optimum spacing for the crop under various fertility levels and for various genotypes.

In french bean, many varieties have been released and their response to spacings and added fertilizers is not known. These in view, the study was initiated with the following objectives.

1. To study the response of genotypes to different levels of fertilizer application and varying spacings.
2. To study the interaction of genotypes to varying fertilizer levels and spacings.
3. To workout the economics of genotypes, spacings and fertilizer levels.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

In this chapter an effort has been made to compile and present all the available literature on growth and yield of french bean in relation to fertilizer levels, spacings and genotypes are reviewed, under the following heads.

A. Fertilizer

2.1 Studies on nitrogen

2.1.1 Effect of nitrogen on growth

Chandra *et al.* (1987) reported that increased plant growth with increasing rates of nitrogen (0-50 kg/ha) in french bean. Hegde and Srinivas (1989) reported that nitrogen application up to 80 kg per ha significantly increased leaf area index, leaf area duration and higher dry matter accumulation. Srinivas and Naik (1990), while studying the growth of french bean with five levels of N per ha, concluded that optimum nitrogen rate to obtain desirable growth was 125.6 kg N per ha. Increased levels of nitrogen (up to 100 kg/ha) increased plant height of french bean (Sridhar and Suryanarayana, 1992). Dahatonde *et al.* (1992) reported that, plant height, number of branches per plant, number of leaves per plant were increased with increasing levels of N up to 120 kg per ha in french bean.

Dwivedi *et al.* (1994) reported that increasing levels of N up to 120 kg per ha showed increased plant height and branches per plant in french bean. Kushwaha, (1994) also reported that increased level of N up to 120 kg per hectare increased significantly the plant height, number of branches per plant and pods per plant.

Pandey *et al.* (1994) reported that, application of 160 kg N per hectare produced maximum number of leaves per plant, length of branches and maximum branching. Singh and Rajput (1995) also studied the effect of nitrogen application and reported that significant increase in growth characters of french bean including plant height, number of leaves and branches per plant up to 120 kg N per hectare except plant canopy area, which significantly increased up to 160 kg N per hectare.

Dahatonde and Nalamwar (1996) reported that plant height increased significantly with increased nitrogen up to 90 kg per hectare. Plant height, number of branches per plant, pod length, number of grains per pod and 100 grain weight were increased with increased level of N up to 160 kg N per hectare (Singh *et al.* 1996). Baboo *et al.* (1998) reported that nitrogen application significantly increased the plant height and number of branches with N levels up to 120 kg per ha. Rana and Singh (1998) also reported that plant height, number of leaves and dry matter accumulation were increased significantly with each increment in N dose up to 120 kg N per hectare.

2.1.2 Effect of nitrogen on yield

Asif and Grieg (1972) reported that nitrogen up to 136 kg per hectare increased the pod yield and higher accumulation of N, P, K, Ca, Mg and Zn in the plants. Applied P and K has no influence on pod yield. Sharma *et al.* (1976) observed that french bean responded significantly up to 60 kg N per hectare and gave maximum yield.

Singh *et al.* (1981) in their study on french bean noticed that seed yield increased (8.7 - 16.6 q/ha) as the rates of nitrogen increased (120 kg/ha) and the difference in seed yield due to any two levels of nitrogen was significant. Srinivas and Rao (1984) reported that pod yields of french bean were highest (89.4 q/ha) with 90 kg N per hectare, however, the optimum level was found to be 60 kg N per hectare (86.9 q/ha).

Srinivas and Prabhakar (1985) while studying the effect of different levels of nitrogen on french bean found that increased yield (53%) of cv. Burpree Stringless with 80 kg N per hectare. The efficiency study carried out in this regard indicated that fertilizing beans with 80 kg N per hectare realised higher yields and returns. Bhopal Singh (1987) in his studies on the effect of four levels of nitrogen (0, 30, 60 and 90 kg/ha) on the green pod yield of french bean found that the pod yield increased with increased levels of N up to 60 kg per ha.

Hegde and Srinivas (1989) reported that french bean cv. Arka Komal gave the highest yield of 132.3 q per ha with 120 kg N per hectare. Hegde and Srinivas (1989) reported that, nitrogen fertilisation significantly increased the green pod yield up to 80 kg per ha. Srinivas and Naik (1990) in their studies with french bean found that the pod yield increased with increasing N levels from 0 to 160 kg per ha (1316 to 3927 kg/ha) and the nitrogen concentration in different plant parts increased with nitrogen application up to 160 kg per ha. Singh and Singh (1990) also reported that application of 0-150 kg N per hectare gave a seed yield of 1.51-2.57 t per ha and noticed increased number pods per plant and hundred seed weight with increase in N rate.

Dahotonde *et al.* (1992) studied varying levels of nitrogen application and found that up to 120 kg N per hectare increased the grain yield, giving the highest yield of 8.77 q per ha. Sridhar and Suryanarayana (1992) reported the increasing levels of nitrogen (100 kg/ha) showed increased trend in french bean pod yield. Dwivedi *et al.* (1994) studied the, seed yield of french bean and found that increased yield (22.6 q/ha) due to increasing levels of N up to 100 kg per ha and significantly higher net returns were also obtained with 400,000 plants population and 80 kg N per ha.

Kushwaha (1994) reported that increasing levels of N significantly increased seed yield in both the years up to 120 kg per ha. However, the difference between 80 and 120 kg N per ha was not marked. Pandey *et al.* (1994) also reported that, the number and weight of green pod per hectare was maximum in N 120 kg per hectare during both the years. Singh and Rajput (1995) also reported that, seed yield (77.74 q/ha) increased with the increase in nitrogen up to 120 kg per hectare.

Dahatonde and Nalamwar (1996) studied seed yield of french bean and found that increased yield with increased N up to 90 kg per hectare. Singh *et al.* (1996) reported seed yield (17.7 q/ha) of french bean increased with increasing N up to 160 kg per ha. However, difference between 120 and 160 kg N per hectare was non-significant. Baboo *et al.* (1998) reported that seed yield increased significantly with each successive increment in N up to 120 kg per ha. This increase in yield was due to significant increase in number of pods per plant, number of seeds per pod and 100 seed weight. Rana *et al.* (1998) reported that, dry matter production of seed (22.1 q/ha) and Straw (33.2 q/ha) increased significantly up to 120 kg N per hectare. Rana and Singh (1998) reported that grain yield (24.4 q/ha) increased with each increment in N dose up to 120 kg N per hectare. Mean increase in grain yield with 120 kg N/ha over 0, 40 and 80 kg N/ha was 66.6, 21.7 and 7.0% respectively.

2.2 Studies on Phosphorus

2.2.1 Effect of Phosphorus on growth

Pandey *et al.* (1974) assessing the effect of three levels of phosphorus application on french bean variety Black prime, found that the plant height decreased significantly with 125 kg P_2O_5 per ha (39.18 cm) while it was 49.28 cm with 75 kg per ha. However number of branches increased from 3.0 to 4.9. Mahatanya (1977) studied the effect of levels of phosphorus on

Phaseolus valgaris L. and concluded that plant height and leaf area index increased with increasing phosphorus levels up to 60 kg per ha.

Gupta *et al.* (1983) studied the effect of phosphorus on french bean variety Contender and found that the phosphorus fertilization had beneficial effects on all plant growth characters. Increasing levels of phosphorus application increased significantly the plant height, number of leaves and number of branches per plant. The plant height was highest (39.6 cm) at 120 kg P_2O_5 per ha, but was on par with at 40 and 80 kg P_2O_5 per ha. The plant height at all the three levels was significantly higher than the control. The number of leaves per plant at all the three levels were significantly higher than that of control (8.4). Chandra *et al.* (1987) observed that increased plant growth with increasing rates of phosphorus (0-80 kg P_2O_5 /ha).

Chakrawarti *et al.* (1990), reported that length of pod, diameter of pod, number of cluster per plant, number of pods per plant, number of seeds per pod was significantly increased with increased level of phosphorus up to 75 kg per ha. Srinivas and Naik (1990) also recorded an increased plant height with the application of phosphorus in vegetable french bean.

Dwivedi *et al.* (1995) reported that, plant height and branches per plant in french bean cv. Contender was significantly higher with phosphorus up to 100 kg N per hectare. Dwivedi *et al.* (1995) also reported the plant height, leaves per plant, branches per plant and leaf area successively increased with increased phosphorus up to 120 kg per ha. Ahlawat (1996) reported that plant height was significantly increased with increased in phosphorus up to 126.4 kg per ha. Baboo *et al.* (1998) reported that phosphorus up to 100 kg per ha had significant effect on growth attributes such as plant height and number of branches. Jasrotia and Sharma (1998) reported that plant height and number of branches per plant was significantly increased with phosphorus application at 80 kg P_2O_5 per ha. Similarly, difference among treatment with respect to leaf area per plant were recorded up to 100 kg P_2O_5 per ha and also pod length. Rana and Singh (1998) reported that plant height, number of leaves and dry matter accumulation increased with increase in phosphorus up to 100 kg per hectare.

2.2.2 Effect of phosphorus on yield

Sharma and Verma (1970) found a good effect of phosphorus fertilization and observed that application of 100 kg P_2O_5 per ha gave the maximum seed yield in french bean variety Contender. Pandey *et al.* (1974) found that pod length, pod weight and number of pods per plant increased with the increase in the doses of P_2O_5, but the differences were not significant. Green pod yield per plant as well as total green pod yield was significantly higher in higher doses of phosphorus in french bean. Similar result have also been reported by Singh *et al.* (1981).

Mahatanya (1977) while studying the response of beans *Phaseolus vulgaris* L. to phosphorus application revealed that the pod number and seed yield per plant and seed yield per square meter increased with the increased phosphorus levels (0, 30 and 60 kg/ha). Bhopal Singh (1987) reported that seed yield of french bean increased as the rate of phosphorus also increased and application of phosphorus at 60 kg and 90 kg per ha were significantly superior to 30 kg P_2O_5 per ha in terms of seed yield (14.5 to 17.3 q/ha).

Gupta *et al.* (1983) studied the effect of phosphorus (0, 40, 80 and 120 kg P_2O_5/ha) on french bean variety Contender and reported the beneficial effect on pod weight, pod length and number of pods per plant. The highest pod yield (120.9 q/ha) was obtained with the application of 120 kg P_2O_5 per ha, which was found to be on par with the yield obtained with 40 and 80 kg P_2O_5 per ha. The yield obtained at all three levels of fertilization was significantly higher than the control. Similar results were also obtained by Sharma *et al.* (1976) and Parodi *et al.* (1977).

Srinivas and Rao (1984) reported that pod yield was highest with 150 kg P_2O_5 per ha and however the optimum level was found to be 123 kg per ha. Srinivas and Prabhakar (1985), studied the french bean cv Burpee Stringless to phosphorus application using four levels of phosphorus (0, 50, 100 and 150 kg P_2O_5 per ha). The yield increased with 150 kg P_2O_5 per ha was 44 per cent. Fertilizing the beans with 150 kg P_2O_5 per ha was found to be beneficial for realising higher yields and returns. Prabhakar *et al.* (1986) studied that, french bean yield increased with phosphorus application up to the level of 75 kg per ha.

Srinivas and Naik (1988) made studies with Arka Komal using three levels of phosphorus (0, 17.5 and 35.0 kg P_2O_5 per ha) obtained the increased pod yield from 1136 kg to 8813 kg per ha by increasing the phosphorus level from 0-35 kg P_2O_5 per ha. Stalin *et al.* (1989) working on french bean variety Premier reported that the plant which received phosphorus at 60 kg per ha recorded the highest pod yield of 13 tonnes per ha. Chakrawarti *et al.* (1990) reported that, pod yield was significantly increased with increased phosphorus levels up to 75 kg per ha.

Srinivas and Naik (1990) assessed the yield and uptake of phosphorus by french bean with three levels of P_2O_5 and it revealed that 143.3 kg P_2O_5 per ha was optimum and nitrogen concentration in leaf decreased with phosphorus fertilization. However, nitrogen concentration in stem and pods increased up to 80 kg P_2O_5 per hectare. Sridhar and Suryanarayan (1992) studying the different levels of phosphorus in french bean varieties observed that the higher level of phosphorus (90kg/ha) produced 32 and 18 per cent more over lower levels of phosphorus (30 & 60 kg/ha) and concluded that phosphorus showed a very significant role in producing higher pod yield.

Singh and Singh (1990) reported that *phaseolus vulgaris* L. responded well to the application of phosphorus as single super phosphate with increase in green pod yield with increased dose of phosphorus. Dwivedi *et al.* (1995) reported that application of 120 kg P_2O_5 per ha produced maximum seed yield (19.11 q/ha) which was 4.29 and 2.04 q/ha higher than those obtained with 40 and 80 kg P_2O_5 per ha respectively.

Dwivedi *et al.* (1995) reported, the seed yield was significantly increased with phosphorus up to 100 kg per ha. This was due to increased pods per plant, seeds per pod and shelling percentage. Ahlawat (1996) studied, yield attributes like pods per plant and seeds per pod which increased with increased in phosphorus level up to 126.4 kg per ha and this improvement in yield attributes was finally increased the seed yield. Phosphorus application greatly improved the N and P uptake. Baboo *et al.* (1998) reported that successive increment in phosphorus dose up to 100 kg per ha led to significant increase in seed yield and yield attributes *viz.*, number of pods per plant, number of grains per pod and 100 seed weight. Jasrotia and Sharma (1998) reported that phosphorus application markedly increased the number of seeds per pod and green pod yield of 31.5-75.9 and 32.0-76.5 q/ha during summer 1993 and 1994 respectively when P was applied at 80 kg per ha. Rana and Singh (1998) reported that french bean fertilized with 100 kg P_2O_5 per ha gave 39.8 and 7.4% more yield over 0 and 50 kg P_2O_5 per ha.

2.3 Studies on potassium

2.3.1 Effect of potassium on growth

While studying the growth response of french bean, Dwivedi *et al.* (1995) found that potassium failed to exert any significant influence on the plant height, number of leaves, number of branches per plant. However, pods per plant, seeds per pod, seed weight and shelling percentage increased with increased potassium up to 50 kg per hectare.

2.3.2 Effect of potassium on yield

Caffey *et al.* (1980) while studying the vegetable yield response to annual fertilization in snap bean and found that highest yield of 8.4 t per ha was obtained with 67 kg K_2O per ha. Illier and Iranov (1990) studied the effect of potash on *Phaseolus vulgaris* and found that potash had no effect on yield. Dwivedi *et al.* (1995) reported that french bean cv Contender gave higher seed yield with potassium up to 50 kg per hectare.

2.4 Cumulative effect of nitrogen, phosphorus and potassium on growth and yield

Caffey *et al.* (1980) studied the different combinations of nitrogen, phosphorus and potassium in the range of 0 to 140 kg per ha. using *Phaseolus vulgaris* cv. Everly Gelatin and found that the addition of NPK mixture had little effect in the beginning, but there after greatly influenced french bean pod yield and was highest (3.4 t/ha) with 67 kg each of N, P_2O_5 and K_2O per ha. Gonzalez *et al.* (1985) reported the seed yield of *Phaseolus vulgaris* was highest (2.07 t /ha) at 80 kg N, 90 kg P_2O_5 per ha. One hundred seed weight was highest (53 g) with 160 kg N, 60 kg P_2O_5 and 90 kg K_2O per ha. Potassium alone had no effect on seed yield and on hundred seed weight.

Saxena and Verma (1994) reported that application of nitrogen affected all the growth attributes and yield significantly up to highest level of nitrogen i.e. 120 kg per ha. Where as phosphorus, on grain yield was noticed up to 60 kg per ha. Potassium, however failed to exhert any significant influence on yield and yield attributes. Thangaraj and Rangaswamy (1994) reported that french bean recorded significantly higher pod yield with 75:60:20 kg NPK per hectare.

Kalyan Sing *et al.* (1996), studied that seed yield and net returns increased with increased NPK 40:30:20 kg per hectare. Gajendra Sing (1997) reported that, the application of NPK 125:70:60 kg per ha produced the highest seed yield of 1.15 t/ha.

B. SPACING

2.5 Studies on plant spacing

2.5.1 Effect of spacings on growth

Pandey *et al.* (1974) studied the effect of three spacing (30, 45 and 60 cm) on the characters of dwarf french bean var Black Prince and found that higher spacing significantly reduced the plant height, but increased the number of branches per plant. Thimmegowda (1987) reported that spacing of 25 x 5 cm produced significantly higher green pod yield of 7.48 tons per ha as compared to 25 x 10 cm (4.62 tons / ha), 25 x 15 cm (4.49 tons/ha) and 25 x 20 cm (4.00 tons/ha).

Halepayati and Ali (1991) studied the response of french bean genotypes to plant densities during spring season and found that an increase in plant density significantly reduced all the growth attributes except plant height. However the dry matter production was more at higher densities. Dwivedi *et al.* (1994) reported plant height and branches per plant were significantly higher in wider row spacing (2,00,000 plants per ha) than closer spacing.

Dwivedi *et al.* (1995) reported that plant height and leaves per plant were unaffected due to different plant spacing but branches per plant and leaf area significantly increased due to wider spacing up to 60 cm x 20 cm. Singh and Rajput (1995) reported that plant geometry had significant effect in increasing growth attributes *viz.*, plant height, number of leaves, branches per plant and plant canopy area. These were highest at wider spacing (30 x 10 cm) over the closer spacing (25 x 10 cm).

Ahlawat (1996) reported that, under higher plant density the crop grew tall owing to competition for light in relatively thickly populated plant community. Singh *et al.* (1996) stated that, in medium spacing (30 cm x 10 cm and 25 cm x 15 cm) plant height, number of branches per plant, pods per plant, pod length, number of grains per pod and 100 grain wt were significantly higher than closer (25 cm x 10 cm) and wider (30 cm x 15 cm) spacings.

2.5.2 Effect of spacings on yield

Ponde *et al.* (1974) studied the effect of three spacing (30,45 and 60 cm) on the characters of dwarf french bean var. Black Prince and found that higher spacing increased the green pod yield per plant and total pod yield. The green pod yield per plant was found to be directly related to the number of branches per plant, but not to the plant height. Mahatanya (1977) studied the response of beans *Phaseolus vulgaris* L. to spacing effect at 50 x 10 cm and found that seed yield per plant was lower, but seed yield per m^2 was greater at closer spacing.

Mack and Hatch (1978) while studying the effects of plant management and population density on yield of bush snap beans *Phaseolus vulgaris* L. suggested that yield was higher when plants were in square arrangement, than when the same population density was in either 12, 24, & 36 inch rows, plants at 5x5 and 6x6 inch spacings (4 to 6 plants per square foot) in a square arrangement produced highest yield when compared to 4x4, 7x7, 8x8 and 9x9 inch spacing. Mack (1983) observed that at higher plant densities (15.20 cm, 43 to 65 plants per m^{2}) yields were 20 to 38 per cent higher compared to lower plant densities (19.4 cm rows, 22 to 29 plants per m^2). Average yield increased with higher plant densities was 29 per cent and crop economic values followed similar trends in bush and snap beans.

Redden *et al.* (1987) studied the response of navy beans to row width and plant population density and found that the established population at harvest was lower than expected, especially at higher populations and at maximum row widths. Ali (1989) found that crops grown at 2,50,000 plants per hectare gave highest yield of 2.33 t/ha and yields were not further increased at higher plant densities in winter season crop.

Krant (1991) reviewed the work on plant density and yield of *phaseolus vlulgaris* L. and reported that the best distribution was 12 to 13 plants per metre. Row spacing used (20, 30 and 40 cm) did not significantly affect production with manual planting, the best yields were obtained with the seed per site, ten seeds per metre and a spacing of 50 cm between rows, however to facilitate management, it is recommended to use 3 to 4 seeds per site and to distribute the seeds linearly within the row for every 10 to 15 cm. Halepayati and Ali (1991) studied the response of french bean genotypes to plant densities during spring season and found that days to 50 per cent flowering decreased with high plant density. Plant densities significantly influenced all the yield attributes. Higher number of pods per plant, number of seeds per pod and hundred seed weight were lower with low plant density. However, the grain yield obtained at higher density was higher, because of higher plant number per unit area.

Prasad *et al.* (1987) studied the effect of inter and intra-row spacing on yield of french bean and found that minimum grain yield (13.97 q/ha) was produced with 30x30 cm. However the difference between 30 x 30 cm and 30 x 25 cm or 25x30 cm was not significant. With decrease in inter and intra-row spacing the yield of french bean increased because an increase in the plant density per ha, which simultaneously increased grain yield. The highest yield was recorded in 25 x 25 cm spacing with 2 seeds per hill. Dwivedi *et al.* (1994) reported that, though plant growth was vigorous under wider row spacing, yield was highest under 30 cm row spacing (400,000 plants/ ha) which was due to higher plant population and the total number of pods per unit area.

Singh and Rajput (1995) reported that significant increase in seed yield (14.27 q/ha) and significantly higher net return (Rs.13,405 per ha) was obtained with plant spacing of 30x10 cm and application of nitrogen up to 120 kg per ha gave the higher net returns (Rs.17355 / ha) and cost benefit ratio (2.02). Dwivedi *et al.* (1995) reported that seed yield per unit area was maximum (20.75 q/ha) with the closet spacing (30 x 20cm).

Ahlawat (1996) reported the greater inter-row competition under higher plant density resulted in reduced number of pods per plant and seeds per pod, compared with lower plant density. More pods per plant under lower density was, however not reflected on seed yield, as it could not compensate for more plants per unit area under higher plant density. The seed yield, therefore remained unaffected by plant density. The higher plant density recorded grater N and P uptake in straw as well as total N and P uptake by the crop. Singh *et al.* (1996) reported seed yield was highest under 30 cm x 10 cm spacing which was at par with 25 cm x 15 cm spacing.

2.6 Studies on fertilizer and spacing interaction

Pondey *et al.* (1974) reported that higher spacing (30 cm) and higher P_2O_5 doses (125 kg/ha) as well as their interactions significantly reduced the plant height but increased the number of branches per plant, green pods, yield per plant and total pod yield. The green pod yield per plant was directly related to the number of branches per plant and not the plant height. Mahatanya (1977) studied the response of beans *Phaseolus vulgaris* L.to spacing and phosphorus application and found that seed yield per plant was lower, but seed yield per m^2 was greater at the closer spacing especially with added phosphorus. Sudhan (1983) reported that phosphorus fertilizer and plant spacing interaction and observed that leaf area and dry weight at 50 days after sowing, number of pods per plant, pod weight seed weight per plant and yield were highest at 20x50 cm spacing with 150 kg P_2O_5 per ha.

Stang *et al.* (1979) reported that in bush snap bean *Phaseolus vulgaris* L., the optimum plant density was directly related to the level of nitrogen fertilization up to 100 kg per ha. It also revealed that higher rates of nitrogen fertilization would be beneficial at higher plant densities and that more effective use of added nitrogen can be expected if plants are grown at higher densities. Mack (1983) reported that there was no significant fertilizer and plant density interactions effect on yields of snap beans (*Phaseolus vulgaris* L.) in field experiments. At higher plant densities, average N, K, Ca and Mg concentrations in leaves at early bloom were lower than at lower densities. Higher fertilizer rates tended to increase N concentration in leaves but had no consistant on P, K, Ca and Mg.

Singh *et al.* (1996) studied the interaction effect of medium plant geometry (30 cm x 10 cm^2) with the higher dose of N (160 kg N per hectare) gave the maximum seed yield. The application of 160 kg N per hectare significantly increased the seed yield under all the spacings. The magnitude of response was higher with increasing in the spacing. Singh and Tripathi (1994) reported that application of fertilizer at 62.5:100:100 kg NPK per hectare with closer spacing (35 x 25 cm^{-2}) produced optimum green pod yield. Highest net return (Rs.18,779.75 per ha) and cost : benefit (1:1.09) ratio was obtained with fertilizer dose of 62.5 : 100:100 kg N:P_2O_5:K_2O per ha was used at closer spacing (35x25cm^{-2}).

C. Studies on varietal performance

Ahlawat and Sharma (1989) reported that genotype PDR -14 recorded higher values of growth and yield attributes and seed yield (14.78 q/ha) compared to VL-63 and HVR-15 with 31.8Kg P_2O_5 per ha.

Kohli *et al.* (1991) reported that cultivars SVM-1 and Kentucky Wonder seed yield increased significantly in both the cultivars under fertility levels P_{100} and K_{25}. The same combination registered heavier 100 seed weight and better seed vigour of harvested seeds. Negi and Shekhar (1993) stated that, genotypes differed significantly for grain yield and yield attributes. Genotype 'B-6' showed significantly higher plant height, branches per plant, pods per plant and grain yield (19.90 q/ha) with 90 kg N per hectare over the B-4, Him-1 and Katrain-1 genotypes.

Jadho (1993) reported that, french bean variety 'VL-63' gave the highest grain yield being significantly higher than HUR-15 and HUR87', might be due to more number of pods per plant with a spacing of 30 cm X 15 cm

(2,22,000 plants/ha). Ahlawat (1996) stated that, variety 'PDR-14' recorded significantly higher seed yield than 'VL-63' and HUR-15' in both the season and showing mean increase of 25.8 and 44.7% respectively. This higher yield may be attributed largely to higher number of pods per plant and bolder seeds. PDR-14 recorded higher N and P uptake in grain and straw as well total N and P uptake than other varieties. The higher nutrient uptake was due to greater production both seed and straw, which constituted the total biomass production.

Baboo *et al.* (1998) reported that cultivar PDR 14 gave the higher yield followed by UPF626 and Contender. Superiority of PDR-14 was due to higher number of pods, number of seeds per pod and 100 seed weight. Saini and Negi (1998) reported that, cultivar Him-1 of french bean (*Pheseolus vulgaris*) gave the improved growth and yield attributes compared to Jawala and local leading to significantly higher grain yield of french bean.

MATERIAL AND METHODS

III. MATERIALS AND METHODS

The details of materials used and techniques adopted in the study on 'Effect of fertilizer levels and spacings on french bean genotypes' was conducted during Kharif, 1998 at the Horticultural Research Station, G.K.V.K., Bangalore are presented in this chapter.

3.1 Location of Experimental site and climate

The Horticultural Research Station, G.K.V.K., Bangalore is located at an elevation of 930 metres above MSL with latitude and longitude at 12°58' North and 77°35' East respectively. The meteorological data collected during crop growth period are presented in Appendix-II.

3.2 Soil properties of experimental site

A plain land having uniform fertility status was selected for the study. The soil samples were collected from a depth of 0-15 cm randomly at three spots. The soil samples were analysed for soil reaction, total soluble salts, organic carbon, available nitrogen, available phosphorus and available potash. The results of the analysis are furnished in Appendix-I.

3.3 Experimental details

3.3.1 Design: Factorial randomized complete block design (FRCBD)

Number of treatments : Eighteen

Number of replications : Three

Gross plot size : 2.8 x 2.4 cm^2 (6.72 sq. m)

3.3.2 Treatment details

There were eighteen treatments consisting of two genotypes, three spacings and three fertilizer levels.

A. Genotypes (G) : 2

G_1 : Arka Komal

G_2 : Burpee Stringless

B. Spacings (S) : 3

S_1 : 30 cm x 15 cm (2,22,222 plants/ha)

S_2 : 30 cm x 20 cm (1,66,666 plants/ha)

S_3 : 40 cm x 20 cm (1,25,000 plants/ha)

C. Fertilizer levels (F) : 3

F_1 : 60: 100: 75 kg NPK /ha

F_2 : 45: 100: 75 kg NPK /ha

F_3 : 75: 100: 75 kg NPK /ha

D. Treatment combinations

$T_1 = G_1S_1F_1$	$T_{10} = G_2S_1F_1$
$T_2 = G_1S_1F_2$	$T_{11} = G_2S_1F_2$
$T_3 = G_1S_1F_3$	$T_{12} = G_2S_1F_3$
$T_4 = G_1S_2F_1$	$T_{13} = G_2S_2F_1$

$T_5 = G_1S_2F_2$ $T_{14} = G_2S_2F_2$

$T_6 = G_1S_2F_3$ $T_{15} = G_2S_2F_3$

$T_7 = G_1S_3F_1$ $T_{16} = G_2S_3F_1$

$T_8 = G_1S_3F_2$ $T_{17} = G_2S_3F_2$

$T_9 = G_1S_3F_3$ $T_{18} = G_2S_3F_3$

3.3.3 Layout of experiment

The experimental site was ploughed, harrowed and leveled after clod crushing and removal of stubbles, the plot was laid out into fifty four plots. The main and sub irrigation channels were laid out taking into consideration, the gradient of site. The treatments were assigned to different plots in each replication by using a random tables. Then furrows were opened at varying levels of spacing.

3.3.4 Application of fertilizer

As per the treatments all the three nutrients were applied in the form of straight fertilizer, nitrogen in the form of urea, phosphorus in the form of single super phosphate and potash in the form of muriate of potash. The urea was applied in two splits *viz.,* at the time of sowing and 30 days after sowing at earthing up and also full dose of single super phosphate and muriate of potash were applied at the time of sowing.

3.3.5 Sowing

As per the treatments, small furrows were opened to a depth of 4-5 cm with the help of marker and at the optimum soil moisture condition two seeds were sown per hill in the furrows as per spacing treatment and it was covered with a layer of soil.

3.3.6 Thinning

After fifteen days of sowing, thinning was done and one healthy seedling was retained per hill.

3.3.7 Inter-culture and Irrigation

Initially, the plots were irrigated once in three to four days depending on the weather condition and soil moisture status. The crop was not allowed to suffer from moisture stress. The plots were kept free from weeds by timely hand weeding.

3.3.8 Earthing up

Earthing up of crop was done at 30 days after sowing. As per fertilizer treatment, top dressing with urea was given along with this operation.

3.3.9 Plant Protection

Crop was infected with a collor rot due to high moisture due to downpour in the month of August and during crop growth period. It was controlled by soil drenching with Blitox 3 g/litre of water (Anon, 1996).

3.3.10 Harvesting (Picking)

The crop was harvested when it reached yellow colour. The first picking was done 75 days after sowing, while the remaining pickings were done at an interval of 5 to 7 days till the final harvest.

3.4 Collection of Experimental Data

3.4.1 Biometric observation

Observations on growth components were made by randomly selected five plants from each treatment and from each replication and it was labelled. All the growth parameters were recorded on these plants.

3.4.1.1 Plant height

This was recorded from the ground level to the terminal growing point of the plant at 30, 45 and 60 days after sowing (DAS) and at harvest. The mean height per plant was calculated and expressed in cm.

3.4.1.2 Number of leaves

Number of fully opened leaves were counted from five randomly labelled plants at 30, 45 and 60 days after sowing and at harvest. The mean of five plants was worked out to get number of leaves per plant.

3.4.1.3 Number of branches per plant

The observations on the number of branches per plant were recorded at 30, 45 and 60 days after sowing and at harvest.

3.4.1.4 Leaf area per plant

Leaf area per plant (cm^2) was recorded at 30, 45 and 60 DAS and at harvest and was calculated by using following formula

Leaf Area = L x B x K

where L = Length of leaf in cm

B = Breadth of leaf in cm

K = Factor (0.59)

3.4.1.5 Leaf area Index (LAI)

The leaf area index was calculated at 30, 45 and 60 DAS and at harvest as suggested by Watson (1952)

$$LAI = \frac{\text{Leaf area per plant (cm}^2)}{\text{Land area occupied by each plant (cm}^2)}$$

3.4.1.6 Leaf Area Duration (LAD)

The leaf area duration was calculated by adopting the following formula

$$LAD\ (dm^2\ day) = \frac{LAI\ 1 + LAI\ 2}{2} \times (t_2 - t_1)$$

Where, LAI_1 - is the leaf area index at time t_1

LAI_2 - is the leaf area index at time t_2

3.4.1.7 Stem girth

Stem girth at the base of each plant was measured using Vernier callipers at 30, 45 and 60 DAS and at harvest and expressed in cm.

3.4.1.8 Spread of the Plant

Spread of the plant in North-South (N-S) direction and in East-West (E-W) direction was recorded at 30, 45 and 60 DAS using a measuring tape and expressed in cm.

3.4.1.9 Dry Matter Accumulation

Five plants were uprooted at 60 DAS and at harvest from each treatment. The roots were washed thoroughly with tap water and the excess water adhering in the roots removed with the help of blotting paper. The leaf, stem, pod and root were separated and cut into small pieces and dried at 70°C in oven till two consecutive weights were constant and expressed in gram per plant.

3.4.2 Yield Parameters

3.4.2.1 Number of pods per plant

Number of pods per plant was recorded at each harvest by counting in each of the selected plants and mean was computed and expressed as number of pods per plant.

3.4.2.2 Length of pod

The length of pod was measured using a measuring scale at harvest and mean was worked out and expressed in cm.

3.4.2.3 Pod weight per plant

The cumulative pod weight was recorded in each of the selected plant and mean was computed and expressed as pod weight per plant in gram.

3.4.2.4 Number of seeds per pod

Number of seeds per pod was worked out by dividing the total number of seeds per plant with total number of pods per plant.

3.4.2.5 Number of seeds per plant

This was taken by counting the seeds at each harvest in all the selected plants and mean was computed and expressed as number of seeds per plant.

3.4.2.6 Seed weight per plant

The seed weight from each harvest was recorded in each of the selected plants and mean was computed and expressed as seed weight per plant in grams.

3.4.2.7 Pod yield

The pod yield obtained from net plot from each harvest were added and the pod yield per hectare was calculated from the following formula

$$\text{Yield per ha (q)} = \frac{\text{Yield per net plot (kg)}}{\text{Net area of plot (m}^2\text{)}} \times 100$$

3.4.2.8 Test weight

One hundred seeds were counted from net plot seed yield and seeds weight was recorded and expressed in grams.

3.4.2.9 Shelling percentage

The shelling percentage of pods was calculated by using the following formula

$$\text{Shelling percentage} = \frac{\text{Weight of seeds}}{\text{Weight of pods}} \times 100$$

3.4.2.10 Harvest index

The harvest index of french bean crop was calculated as suggested by Donald (1962)

$$\text{Harvest index} = \frac{\text{Dry matter of pod}}{\text{Dry matter of plant}}$$

3.4.3 Plant tissue analysis

The plant samples used for recording drymatter production at harvest were used for estimation of nutrients present in plant parts. After recording the dry weight from each treatment, the samples were powdered in a micro-willey mill. These samples were analysed for accumulation of different nutrient (%) present in different plant parts.

3.4.3.1 Nitrogen accumulation

The accumulation of nitrogen in the plant samples was estimated by microkjeldhal method as per the procedure described by Jackson (1973).

3.4.3.2 Phosphorus accumulation

The accumualtion of phosphorus in the samples was analysed by vanadomolybdate yellow colour as suggested by Jackson (1973).

3.4.3.3 Potassium accumulation

The accumulation of potassium in the samples was analysed by using flamephotometer as outlined by Jackson (1973).

3.4.3.4 Nutrient uptake

Nitrogen, phosphorus and photassium contents were used to work out the uptake from different plant parts. The uptake of nitrogen, phosphorus and potassium was calculated by multiplying the dry weight of respective parts with percentage of corresponding nutrients and expressed as kg per ha. From these, total uptake per ha was computed by mathematical addition of the uptake from different plant parts.

3.4.4 Soil Analysis

3.4.4.1 Soil reaction (pH)

The pH of the soil was measured in 1:2.5 soil water suspension, stirring intermittently for 30 minutes. The pH was recorded by using a single electrode pH meter (Toshniwal Model *c1.2*)

3.4.4.2 Electrical conductivity

The soil water suspension used for measuring the pH value was filtered and the total soluble salts was measured from electrical conductivity by using a conductivity bridge (Elico CM 81) (Jackson, 1973).

3.4.4.3 Organic carbon

Organic carbon percentage was estimated by Walkley and Black rapid titration method (Jackson, 1973).

3.4.4.4 Available nitrogen

The available nitrogen content was determined by alkaline permanganate method through digestion, distillation and collection of ammonia in the per cent boric acid and then titrating against standard sulphuric acid (Subbaiah and Asiza, 1956).

3.4.4.5 Available phosphorus

The available phosphorus was determined by Bray's No-1 extractant method. Phosphorus in the filtered extract was determined by chloro-stannous reduced molybdo phosphate blue colour method. The intensity of colour was read on U.V. Spectometer (Jackson, 1973).

3.4.4.6 Available potassium

The neutral ammonium acetate extract of soil was used to determine available potassium after shaking for 30 minutes on AIML Flame Photometer (Jackson, 1973).

3.4.5 Economics

In computing economics, the varying doses of fertilizer seed cost due to different spacings and the differential cost of Arka Komal and Burpee Stringless genotypes were taken into consideration apart from costs common to all the treatments as per package of practices.

The total value of the actual produce was calculated and the net income was worked out by deducting the cost of cultivation from the value of actual produce. The cost : benefit (C:B) ratio was worked out using net income.

3.4.6 Statistical Analysis

The experimental data collected on various parameter were statistically analyzed using Fortous Computer at UAS, Bangalore. The level of significance in 'F' test was at 5 per cent probability. The results are presented and discussed in the text at above said probability level, unless otherwise stated.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the experiment conducted at Horticulture Research Station, G.K.V.K, Bangalore during Kharif 1998 to study the "Effect of fertilizer, spacings and their interactions on growth and yield of french bean genotypes" are presented in this chapter.

4.1 Growth Parameters

4.1.1 Plant height

The data on plant height at 30, 45, 60 days after sowing (DAS) and at harvest as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.1 and 4.1a.

Plant height differed significantly among genotypes at 60 DAS and at harvest. It was non-significant at 30 and 45 DAS (Table 4.1). Significantly higher plant height at 60 DAS and at harvest was in Arka Komal (G_1) (37.10 and 39.33 cm respectively) over the Burpee Stringless (G_2) at 60 DAS and at harvest (35.86 and 37.40 cm respectively).

Significantly higher plant height was in spacing S_3 at 30, 60 DAS and at harvest (20.29, 39.38 and 41.54 cm respectively). The lowest was in spacing S_1 at 30, 60 DAS and at harvest (17.52, 33.28 and 35.05 cm respectively). At 45 DAS, Plant height in spacings S_3 and S_2 were at par (28.52 and 27.28 cm respectively) and the lowest plant height (25.42 cm) was in spacing S_1.

Plant height differed significantly with respect to fertilizer levels at all stages of plant growth (Table 4.1). At 30 DAS, significantly higher plant height (20.05 cm) was in fertilizer level F_3 over the fertilizer level F_2 (17.83

Table 4.1 : Plant height (cm) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

	Days after sowing			
Treatments	30	45	60	At harvest
Genotypes (G)				
G_1	19.40	27.62	37.10	39.33
G_2	18.73	26.53	35.86	37.40
S. Em ±	0.27	0.39	0.31	0.28
CD (P = 0.05)	N S	NS	0.87	0.77
Sapcings (S)				
S_1	17.52	25.42	33.28	35.05
S_2	19.39	27.28	67.77	38.53
S_3	20.29	28.52	39.38	41.54
S. Em ±	0.32	0.48	0.38	0.34
CD (P = 0.05)	0.88	1.32	1.06	0.94
Fertilizer levels (F)				
F_1	19.31	27.20	36.43	38.25
F_2	17.83	26.20	34.71	36.98
F_3	20.05	27.82	38.29	39.89
S. Em ±	0.32	0.48	0.38	0.34
CD (P = 0.05)	0.88	1.32	1.06	0.94
CV. (%)	7.03	7.48	4.45	3.77

N.S = Non-significant

Table 4.1a : Plant height (cm) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

Treatments	DAYS AFTER SOWING 30 G_1	30 G_2	45 G_1	45 G_2	60 G_1	60 G_2	At harvest G_1	At harvest G_2
Genotypes (G) x Spacings (S)								
S_1	18.20	16.83	26.90	24.64	33.52	33.03	35.21	34.88
S_2	19.59	19.19	27.77	26.79	37.28	36.25	39.66	37.40
S_3	20.40	20.16	28.90	28.15	40.46	38.30	43.13	39.94
S.Em ±		0.45		0.67		0.54		0.48
CD (P = 0.05)		NS		NS		NS		NS
Genotypes (G) x Fertilizer levels (F)								
F_1	19.77	18.01	27.85	26.54	36.94	35.91	39.18	37.30
F_2	18.84	20.78	26.60	28.55	35.18	34.23	37.77	36.17
F_3	17.65	19.32	28.41	27.23	39.14	37.43	41.04	38.74
S.Em ±		0.45		0.67		0.54		0.48
CD (P = 0.05)		NS		NS		NS		NS

Fertilizer levels (F) x Spacings (S)	30 F_1	30 F_2	30 F_3	45 F_1	45 F_2	45 F_3	60 F_1	60 F_2	60 F_3	At harvest F_1	At harvest F_2	At harvest F_3
S_1	17.93	16.28	18.32	25.70	24.13	26.42	33.52	30.61	35.83	34.80	33.58	36.7
S_2	19.45	18.15	20.57	27.39	26.51	27.94	36.58	35.32	38.40	38.66	37.17	39.7
S_3	20.54	19.06	21.25	28.51	27.97	29.09	39.31	38.19	40.63	41.27	40.18	43.1
S.Em ±			0.55			0.83			0.66			0.5
CD (P = 0.05)			NS			NS			NS			NS

Genotypes (G) x Spacings (S) x Fertilizer levels (F)	30 G_1	30 G_2	45 G_1	45 G_2	60 G_1	60 G_2	At harvest G_1	At harvest G_2
S_1F_1	18.93	16.93	26.80	24.60	33.61	33.17	35.20	34.41
S_1F_2	16.26	16.31	24.47	23.80	30.80	30.43	33.43	33.73
S_1F_3	19.43	17.26	27.31	25.53	36.17	35.49	36.99	36.51
S_2F_1	19.65	19.25	27.84	26.93	36.67	36.50	39.67	37.67
S_2F_2	17.71	18.59	27.22	25.80	35.71	34.93	38.50	35.83
S_2F_3	21.41	19.72	28.24	27.64	39.48	37.33	40.83	38.70
S_3F_1	20.73	20.33	28.90	28.11	40.51	38.08	42.70	39.84
S_3F_2	18.98	19.14	28.13	27.81	39.04	37.34	41.39	38.97
S_3F_3	21.51	21.00	29.67	28.52	41.80	39.47	45.30	41.02
S.Em ±		0.78		1.17		0.94		0.08
CD (P = 0.05)		NS		NS		NS		NS
CV (%)		7.03		7.48		4.45		3.77

NS = Non-significant

cm) but, it was on par with fertilizer level F_1 (19.31 cm). Similar trend was observed at 45 DAS.

Plant height did not differ significantly to all interactions (Table 4.1a).

4.1.2 Number of leaves per plant

The data on number of leaves per plant at 30, 45, 60 DAS and at harvest as affected by genotypes, spacings and fertilizer levels and their interaction are presented in Tables 4.2 and 4.2a.

The number of leaves per palnt was differed significantly among genotypes at all stages of plant growth (Table 4.2) Significantly higher number of leaves per plant was in Arka Komal (G_1) at 30, 45, 60 DAS and at harvest (9.07, 10.49, 14.02 and 9.44 respectively) over the Burpee Stringless (G_2) at 30, 45, 60 DAS and at harvest (8.13, 9.83, 13.29 and 9.09 respectively).

Significantly higher number of leaves per plant at 30, 45, 60 DAS and at harvest was in spacing S_3 (9.20, 11.71, 15.22 and 10.33 respectively) followed by spacing S_2 at 30, 45, 60 DAS and at harvest (8.78, 10.07, 13.54 and 9.30 respectively). Significantly lower number of leaves per plant at 30, 45, 60 DAS and at harvest was in spacing S_1 (7.81, 9.17, 12.20 and 8.18 respectively).

Number of leaves per plant was significantly higher in fertilizer level F_3 at 30, 45, 60 DAS and at harvest (9.01, 10.95, 14.53 and 9.69 respectively) followed by fertilizer level F_1 at 30, 45, 60 DAS and at harvest (8.61, 10.71, 13.62 and 9.27 respectively). Significantly lower number of leaves per plant was in fertilizer level F_2 at 30, 45, 60 DAS and at harvest (8.18, 9.84, 12.84 and 8.84 respectively).

Table 4.2 : Number of leaves at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

	Days after sowing			
Treatments	30	45	60	At harvest
Genotypes (G)				
G_1	9.07	10.49	14.02	9.44
G_2	8.13	9.84	13.29	9.09
S. Em ±	0.08	0.12	0.19	0.07
CD (P = 0.05)	0.23	0.33	0.53	0.20
Sapcings (S)				
S_1	7.81	9.17	12.20	8.18
S_2	8.78	10.07	13.54	9.30
S_3	9.20	11.71	15.22	10.33
S. Em ±	0.10	0.15	0.08	0.09
CD (P = 0.05)	0.29	0.41	0.24	0.24
Fertilizer levels (F)				
F_1	8.61	10.17	13.62	9.27
F_2	8.18	9.84	12.82	8.84
F_3	9.01	10.95	14.53	9.69
S. Em ±	0.10	0.14	0.23	0.09
CD (P = 0.05)	0.29	0.41	0.64	0.24
CV. (%)	5.10	6.13	7.23	4.02

Table 4.2a : Number of leaves at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

	DAYS AFTER SOWING											
Treatments	30			45			60			At harvest		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	8.32	7.30		9.50	8.84		12.57	11.83		8.28	8.08	
S_2	9.30	8.26		10.44	9.71		13.78	13.30		9.41	9.19	
S_3	9.57	8.83		12.11	11.31		15.71	14.74		10.63	10.02	
S.Em ±		0.15			0.21			0.33			0.12	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)												
F_1	9.02	8.20		10.49	9.84		13.91	13.33		9.47	8.08	
F_2	8.77	7.57		10.25	9.43		13.16	12.47		8.96	8.72	
F_3	9.40	8.62		11.31	10.59		14.99	14.07		9.90	9.49	
S.Em ±		0.15			0.21			0.33			0.12	
CD (P = 0.05)		NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	7.72	7.31	8.40	9.11	8.85	9.55	12.38	11.48	12.73	8.27	7.90	8.37
S_2	8.73	8.48	9.13	9.78	9.53	10.91	13.61	12.66	14.37	9.27	8.90	9.73
S_3	9.38	8.73	9.50	11.60	11.15	12.38	14.86	14.31	16.50	10.28	9.72	10.99
S.Em ±			0.18			0.26			0.40			0.15
CD (P = 0.05)			NS			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	8.10	7.33		9.43	8.80		12.73	12.03		8.37	8.17	
S_1F_2	7.87	6.77		9.20	8.50		11.87	11.10		8.00	7.80	
S_1F_3	9.00	7.80		9.87	9.23		13.10	12.36		8.47	8.27	
S_2F_1	9.33	8.13		10.03	9.53		13.87	13.36		9.43	9.10	
S_2F_2	9.07	7.90		9.80	9.27		12.79	12.52		9.00	8.80	
S_2F_3	9.50	8.77		11.50	10.33		14.70	14.03		9.80	9.67	
S_3F_1	9.63	9.13		12.00	11.20		15.13	14.59		10.60	9.97	
S_3F_2	9.40	8.07		11.77	10.53		14.83	13.79		9.88	9.57	
S_3F_3	9.70	9.30		12.57	12.20		17.17	15.83		11.43	10.55	
S.Em ±		0.25			0.36			0.57			0.21	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		5.10			6.13			7.23			4.02	

NS = Non-significant

Number of leaves per plant did not differ significantly among the interactions of genotypes, spacing and fertilizer levels (Table 4.2a).

4.1.3 Number of branches per plant

The data on number of branches per plant at 30, 45, 60 DAS and at harvest as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.3 and 4.3a.

Number of branches per plant were at par among genotypes at all stages of plant growth (Table 4.3).

Significantly higher number of branches per plant was in spacing S_3 at 30, 45, 60 DAS and at harvest (2.23, 3.84, 4.98 and 5.03 respectively) followed by spacing S_2 at 30, 45, 60 DAS and at harvest (1.92, 3.45, 4.47 and 4.59 respectively). Significantly the lowest number of branches per plant was in spacing S_1 at 30, 45, 60 DAS and at harvest (1.69, 3.05, 4.15 and 4.39 respectively).

Number of branches per plant was significantly higher in fertilizer level F_3 at 45, 60 DAS and at harvest (3.66, 4.78 and 5.03 respectively) followed by fertilizer level F_1 at 45, 60 DAS and at harvest (3.44, 4.53 and 4.77 respectively). Significantly the lowest number of branches per plant was in fertilizer level F_2 at 45, 60 DAS and at harvest (3.25, 4.27 and 4.59 respectively). At 30 DAS, higher number of branches per plant (2.06) was in fertilizer level F_3 but was on par with fertilizer level F_1 (1.93). The lowest was in fertilizer level F_2 (1.85) which was on par with fertilizer level F_1.

Number of branches per plant at harvest differed significantly in the interaction of genotypes X fertilizer. It was non-significant in the interaction of genotypes x fertilizer, fertilizer x spacing and genotypes x spacings x fertilizer levels. (Table 4.3a).

Table 4.3 : Number of branches per plant at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

Treatments	Days after sowing			
	30	45	60	At harvest
Genotypes (G)				
G_1	1.96	3.48	4.55	4.82
G_2	1.93	3.41	4.50	4.78
S. Em ±	0.05	0.05	0.03	0.03
CD (P = 0.05)	NS	NS	NS	NS
Sapcings (S)				
S_1	1.69	3.05	4.15	4.39
S_2	1.92	3.45	4.47	4.59
S_3	2.23	3.84	4.98	5.03
S. Em ±	0.06	0.06	0.03	0.03
CD (P = 0.05)	0.15	0.17	0.09	0.09
Fertilizer levels (F)				
F_1	1.93	3.44	4.53	4.77
F_2	1.85	3.25	4.27	4.59
F_3	2.06	3.66	4.78	5.03
S. Em ±	0.06	0.06	0.03	0.03
CD (P = 0.05)	0.15	0.17	0.09	0.09
CV. (%)	12.19	12.19	3.10	2.84

NS = Non-significant

Table 4.3a : Number of branches per plant at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

Treatments	DAYS AFTER SOWING 30		45		60		At harvest	
	G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2
Genotypes (G) x Spacings (S)								
S_1	1.75	1.62	3.13	2.97	4.14	4.15	4.38	4.41
S_2	1.92	1.92	3.42	3.49	4.50	4.44	4.71	4.77
S_3	2.20	2.25	3.90	3.79	5.01	4.92	5.37	5.17
S.Em ±		0.08		0.09		0.05		0.04
CD (P = 0.05)		NS		NS		NS		0.13
Genotypes (G) x Fertilizer levels (F)								
F_1	1.95	1.90	3.50	3.38	4.58	4.49	4.79	4.75
F_2	1.82	1.88	3.19	3.31	4.25	4.29	4.63	4.55
F_3	2.10	2.02	3.78	3.55	4.82	4.74	5.03	5.03
S.Em ±		0.08		0.09		0.05		0.04
CD (P = 0.05)		NS		NS		NS		NS

Fertilizer levels (F) x Spacings (S)	30 F_1	30 F_2	30 F_3	45 F_1	45 F_2	45 F_3	60 F_1	60 F_2	60 F_3	At harvest F_1	At harvest F_2	At harvest F_3
S_1	1.70	1.55	1.82	3.00	2.90	3.25	4.17	3.95	4.33	4.35	4.17	4.67
S_2	1.93	1.82	2.02	3.47	3.27	3.63	4.48	4.25	4.68	4.78	4.55	4.88
S_3	2.15	2.18	2.35	3.85	3.58	4.10	4.95	4.62	5.33	5.18	5.06	5.55
S.Em ±			0.10			0.11			0.06			0.06
CD (P = 0.05)			NS			NS			NS			NS

Genotypes (G) x Spacings (S) x Fertilizer levels (F)	30 G_1	30 G_2	45 G_1	45 G_2	60 G_1	60 G_2	At harvest G_1	At harvest G_2
S_1F_1	1.77	1.63	3.07	2.93	4.17	4.17	4.33	4.36
S_1F_2	1.60	1.50	2.93	2.87	3.90	4.00	4.20	4.13
S_1F_3	1.90	1.73	3.40	3.10	4.37	4.30	4.60	4.73
S_2F_1	1.93	1.93	3.50	3.43	4.57	4.40	4.77	4.80
S_2F_2	1.80	1.83	3.13	3.40	4.23	4.27	4.53	4.57
S_2F_3	2.03	2.00	3.63	3.63	4.70	4.67	4.83	4.93
S_3F_1	2.17	2.13	3.93	3.77	5.00	4.90	5.27	5.10
S_3F_2	2.07	2.30	3.50	3.67	4.63	4.60	5.17	4.97
S_3F_3	2.37	2.33	4.27	3.93	5.40	5.27	5.67	5.43
S.Em ±		0.14		0.15		0.08		0.08
CD (P = 0.05)		NS		NS		NS		NS
CV (%)		12.19		7.67		3.10		2.84

NS = Non-significant

Significantly higher number of branches per plant at harvest was in interaction G_1S_3 (5.37) followed by G_2S_3 and the differences among them being singnificant. The interactions G_2S_3 and G_1S_2 were at par. Significantly lowest number of branches per plant at harvest was in interaction G_1S_1 (4.38) which was on par with G_2S_1 (4.41).

4.1.4 Leaf area per plant

The data on leaf area per plant at 30, 45, 60 DAS and at harvest as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.4 and 4.4a.

Leaf area per plant differed significantly among genotypes at all stages of plant growth except at harvest (Table 4.4). It was significantly higher in Arka Komal (G_1) at 30, 45 and 60 DAS (1070.67, 1548.40 and 2001.86 cm2 respectively) over the Burpee Stringless (G_2) at 30, 45 and 60 DAS (990.37, 1404.78 and 1884.57 cm^2 respectively).

Leaf area per plant was significantly higher in spacing S_3 at 30, 45, 60 DAS and at harvest (1174.95, 1741.28, 2248.53 and 1441.53 cm^2 respectively) followed by spacing S_2 at 30, 45, 60 DAS and at harvest (1045.95, 1453.36, 1911.82 and 1266.18 cm^2 respectively).

Significantly higher leaf area per plant was in fertilizer level F_3 at 30, 45, 60 DAS and at harvest (1105.09, 1597.22, 2055.79 and 1372.60 cm^2 respectively) followed by fertilizer level F_1 at 30, 45, 60 DAS and at harvest (1030.52, 1461.57, 1951.46 and 1267.98 cm^2 respectively) and the differences among them being significant. Significantly lowest was in fertilizer level F_2 at 30, 45, 60 DAS and at harvest (981.86, 1370.98, 1822.39 and 1175.24 cm^2 respectively).

Table 4.4 : Leaf area (cm^2) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

Treatments	Days after sowing			
	30	45	60	At harvest
Genotypes (G)				
G_1	1070.67	1548.40	2001.86	1277.34
G_2	990.37	1404.78	1884.57	1266.53
S. Em ±	7.68	17.08	16.55	20.03
CD (P = 0.05)	21.29	47.33	45.89	NS
Sapcings (S)				
S_1	896.58	1235.14	1669.29	1108.09
S_2	1045.95	1453.36	1911.82	1266.18
S_3	1174.95	1741.28	2248.53	1441.53
S. Em ±	9.41	20.92	20.28	24.53
CD (P = 0.05)	26.08	57.98	56.20	67.98
Fertilizer levels (F)				
F_1	1030.52	1461.57	1951.46	1267.98
F_2	981.86	1370.98	1822.39	1175.24
F_3	1105.09	1597.22	2055.79	1372.60
S. Em ±	9.41	20.92	20.29	24.53
CD (P = 0.05)	26.08	57.98	56.20	67.98
CV. (%)	3.84	6.01	4.43	8.18

NS = Non-significant

Table 4.4a : Leaf area (cm^2) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

	DAYS AFTER SOWING							
	30		45		60		At harvest	
	G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2
Genotypes (G) x Spacings (S)								
S_1	949.51	843.64	1312.85	1157.43	1737.83	1600.74	1114.17	1102.02
S_2	1071.90	1020.00	1543.78	1362.93	1937.10	1886.53	1269.57	1262.79
S_3	1193.53	1156.37	1788.58	1693.96	2330.63	2166.42	1448.29	1434.78
S.Em ±		13.31		29.58		28.69		34.69
CD (P = 0.05)		36.89		NS		NS		NS
Genotypes (G) x Fertilizer levels (F)								
F_1	1070.67	990.37	1536.16	1386.97	2010.42	1892.49	1273.45	1262.50
F_2	1011.61	952.37	1446.99	1294.97	1859.79	1784.99	1155.79	1194.69
F_3	1132.67	1077.52	1662.05	1532.39	2135.36	1976.22	1402.79	1342.40
S.Em ±		13.31		29.58		28.69		34.69
CD (P = 0.05)		NS		NS		NS		NS

Fertilizer levels (F) x Spacings (S)	30			45			60			At harvest		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	883.03	856.47	950.23	1222.83	1134.13	1348.96	1674.46	1550.36	1783.05	1106.21	1010.20	1207.87
S_2	1015.40	982.85	1139.60	1428.85	1341.55	1589.66	1912.34	1829.61	1993.50	1258.69	1185.41	1354.46
S_3	1193.13	1106.27	1225.46	1733.02	1637.26	1853.55	2267.57	2087.19	2390.82	1439.03	1330.10	1557.47
S.Em ±			16.30			36.23			35.12			42.48
CD (P = 0.05)			45.18			NS			NS			NS

Genotypes (G) x Spacings (S) x Fertilizer levels (F)	30		45		60		At harvest	
	G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2
S_1F_1	950.72	815.34	1303.27	1142.39	1745.22	1603.70	1137.99	1074.44
S_1F_2	916.65	796.30	1178.33	1089.93	1608.67	1492.04	1000.64	1019.76
S_1F_3	981.17	919.30	1456.95	1239.97	1859.61	1706.49	1203.87	1211.87
S_2F_1	1033.50	997.32	1518.39	1339.31	1926.46	1898.23	1249.99	1267.38
S_2F_2	1002.30	963.39	1459.54	1223.57	1826.46	1833.08	1188.85	1181.97
S_2F_3	1179.92	1099.29	1653.40	1525.92	2058.71	1928.30	1369.88	1339.04
S_3F_1	1227.79	1158.47	1786.82	1679.23	2358.59	2175.55	1432.37	1445.69
S_3F_2	1115.89	1096.65	1703.11	1571.40	2144.56	2029.83	1277.88	1382.33
S_3F_3	1236.93	1213.99	1875.80	1831.29	2487.76	2293.88	1634.63	1476.30
S.Em ±		23.050		51.240		49.680		60.080
CD (P = 0.05)		NS		NS		NS		NS
CV (%)		3.84		6.01		4.43		8.18

NS = Non-significant

The leaf area per plant differed significantly to interaction of genotypes x spacings and fertilizer x spacings only at 30 DAS. It was non-significant to remaining stages of plant growth to interaction of genotypes x fertilizer and genotypes x spacings x fertilizer levels (Table 4.4a).

Significantly higher leaf area per plant was in G_1S_3 and G_2S_3 combination (1193.53 and 1156.37 cm^2respectively). Interactions G_1S_2 and G_2S_3 (1071.90 and 1020.00 cm^2respectively) were at par. The lowest leaf area per plant was in the combination G_2S_1 (843.64 cm^2) which was on par with G_1S_1 (949.51 cm^2).

Leaf area per plant at 30 DAS was significantly higher in F_3S_3, F_1S_3 and F_3S_2 interactions (1225.46, 1193.13 and 1139.60 cm^2 respectively). Interactions F_2S_3, F_1S_2, F_2S_2 were at par (1106.27, 1015.40 and 982.85 cm^2respectively). Significantly lower leaf area per plant at 30 DAS was in F_3S_1, F_1S_1 and F_2S_1 combination (950.23, 883.03 and 856.47 cm^2 respectively).

4.1.5 Leaf area Index (LAI)

The data on LAI at 30, 45, 60 DAS and at harvest as influenced by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.5 and 4.5a.

Leaf area index differed significantly among genotypes at all stages of plant growth except at harvest (Table 4.5). Arka Komal (G_1) recorded significantly higher LAI at 30, 45 and 60 DAS (1.79, 2.57 and 3.33 respectively) over the Burpee Stringless (G_2) at 30, 45 and 60 DAS (1.67, 2.31 and 3.14 respectively).

Significantly higher LAI was in spacing S_1 at 30, 45, 60 DAS and at harvest (1.99, 2.74, 3.7 and 3.9 respectively). This was followed by spacing

Table 4.5 : Leaf area index at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

	Days after sowing			
Treatments	30	45	60	At harvest
Genotypes (G)				
G_1	1.79	2.57	3.33	2.12
G_2	1.67	2.31	3.14	2.11
S. Em ±	0.01	0.03	0.03	0.03
CD (P = 0.05)	0.03	0.08	0.08	NS
Sapcings (S)				
S_1	1.99	2.74	3.70	2.46
S_2	1.74	2.42	3.20	2.10
S_3	1.46	2.17	2.81	1.78
S. Em ±	0.01	0.04	0.04	0.04
CD (P = 0.05)	0.04	0.10	0.10	0.12
Fertilizer levels (F)				
F_1	1.71	2.42	3.26	2.09
F_2	1.64	2.26	3.03	1.95
F_3	1.84	2.65	3.42	2.29
S. Em ±	0.01	0.04	0.04	0.04
CD (P = 0.05)	0.04	0.10	0.10	0.12
CV. (%)	3.83	6.73	4.73	8.57

NS = Non-significant

Table 4.5a : Leaf area index at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

Treatments	30 DAS G_1	30 DAS G_2	45 DAS G_1	45 DAS G_2	60 DAS G_1	60 DAS G_2	At harvest G_1	At harvest G_2
Genotypes (G) x Spacings (S)								
S_1	2.10	1.87	2.91	2.57	3.86	3.55	2.47	2.44
S_2	1.78	1.69	2.57	2.26	3.22	3.17	2.11	2.10
S_3	1.49	1.44	2.23	2.11	2.91	2.70	2.18	1.78
S.Em ±		0.02		0.05		0.05		0.06
CD (P = 0.05)		NS		NS		NS		NS
Genotypes (G) x Fertilizer levels (F)								
F_1	1.78	1.64	2.55	2.28	3.34	3.12	2.10	2.09
F_2	1.69	1.58	2.39	2.14	3.09	2.96	1.93	1.98
F_3	1.89	1.79	2.78	2.52	3.55	3.29	2.33	2.25
S.Em ±		0.02		0.05		0.05		0.06
CD (P = 0.05)		NS		NS		NS		NS

Fertilizer levels (F) x Spacings (S)

Treatments	30 DAS F_1	30 DAS F_2	30 DAS F_3	45 DAS F_1	45 DAS F_2	45 DAS F_3	60 DAS F_1	60 DAS F_2	60 DAS F_3	At harvest F_1	At harvest F_2	At harvest F_3
S_1	1.96		2.11	2.71	2.51	2.99	3.71	3.44	3.96	2.45	2.09	1.74
S_2	1.69	1.63	1.89	2.38	2.23	2.64	3.23	3.04	3.32	2.24	1.97	1.66
S_3	1.49	1.38	1.53	2.16	2.04	2.31	2.83	2.60	2.98	2.68	2.26	1.94
S.Em ±			0.03			0.06			0.06			0.07
CD (P = 0.05)			NS			NS			NS			NS

Genotypes (G) x Spacings (S) x Fertilizer levels (F)

Treatments	30 DAS G_1	30 DAS G_2	45 DAS G_1	45 DAS G_2	60 DAS G_1	60 DAS G_2	At harvest G_1	At harvest G_2
S_1F_1	2.12	1.81	2.89	2.53	3.87	3.56	2.52	2.38
S_1F_2	2.03	1.76	2.61	2.42	3.57	3.31	2.22	2.26
S_1F_3	2.17	2.04	3.23	2.75	4.13	3.79	2.67	2.67
S_2F_1	1.72	1.66	2.53	2.23	3.20	3.25	2.80	2.11
S_2F_2	1.67	1.60	2.43	2.03	3.04	3.05	1.98	1.97
S_2F_3	1.96	1.83	2.75	2.54	3.43	3.21	2.29	2.23
S_3F_1	1.53	1.44	2.23	2.09	2.94	2.72	1.70	1.78
S_3F_2	1.39	1.37	2.12	1.96	2.68	2.53	1.59	1.84
S_3F_3	1.54	1.51	2.34	2.28	3.12	2.86	2.04	0.10
S.Em ±		0.04		0.09		0.09		60.08
CD (P = 0.05)		NS		NS		NS		NS
CV (%)		3.83		6.47		4.73		8.57

NS = Non-significant

S_2 at 30, 45, 60 DAS and at harvest (1.74, 2.42, 3.20 and 2.10 respectively). Leaf area index was significantly lower in spacing S_3 at 30, 45, 60 DAS and at harvest (1.46, 2.17, 2.81 and 1.78 respectively).

Leaf area index was significantly higher in fertilizer level F_3 at 30, 45, 60 DAS and at harvest (1.84, 2.65, 3.42 and 2.29 respectively), followed by fertilizer level F_1 at 30, 45, 60 DAS and at harvest (1.71, 2.42, 3.26 and 2.09 respectively) and the differences among them being significant. Fertilizer level F_2 at 30, 45, 60 DAS and at harvest recorded significantly lower LAI (1.64, 2.26, 3.03 and 1.95 respectively).

Interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer x spacings and genotypes x spacings x fertilizer levels did not influence significantly on LAI (Table 4.5a).

4.1.6 Leaf area duration (LAD)

The data on LAD at 30-45 and 46-60 days as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.6 and 4.6a.

The LAD differed significantly among genotypes at both stages of sampling (Table 4.6). Significantly higher LAD was in Arka Komal (G_1) at 30-45 days and 46-60 days (32.7 and 43.86 dm^2 day respectively). Significantly lowest was in Burpee Stringless (G_2) at 30-45 days and 46-60 days (29.88 and 41.15 dm^2 day respectively).

The LAD differed significantly with respect to various spacings at both the stages of sampling. Spacing S_1 recorded significantly higher LAD at 30-45 days and 46-60 days (35.46 and 47.60 dm^2 day respectively). This was followed by spacing S_2 at 30-45 days and 46-60 days (31.17 and 42.28 dm^2 day respectively). Significantly lowest LAD

Table 4.6 : Leaf area duration (dm^2 day) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

Treatments	Days after sowing 30-45 days	46-60 days
Genotypes (G)		
G_1	32.71	43.86
G_2	29.88	41.15
S. Em ±	0.28	0.56
CD (P = 0.05)	0.77	1.55
Sapcings (S)		
S_1	35.45	47.60
S_2	31.17	42.28
S_3	27.27	37.64
S. Em ±	0.34	0.69
CD (P = 0.05)	0.94	1.90
Fertilizer levels (F)		
F_1	30.95	42.75
F_2	29.24	39.98
F_3	33.70	44.80
S. Em ±	0.34	0.69
CD (P = 0.05)	0.94	1.90
CV. (%)	4.62	6.86

Table 4.6a : Leaf area duration (dm^{2}day) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

	DAYS AFTER SOWING					
Treatments	30-45 days			46-60 dsys		
	G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)						
S_1	37.61	33.29		49.00	46.20	
S_2	32.63	29.71		43.73	40.84	
S_3	27.89	26.65		38.85	36.42	
S.Em ±		0.48			0.97	
CD (P = 0.05)		1.34			NS	
Genotypes (G) x Fertilizer levels (F)						
F_1	32.40	29.41		44.46	41.01	
F_2	30.62	27.85		41.41	38.55	
F_3	35.02	32.28		45.71	43.89	
S.Em ±		0.48			0.97	
CD (P = 0.05)		NS			NS	
Fertilizer levels (F) x Spacings (S)						
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	35.03	33.08	38.25	48.50	44.96	49.35
S_2	30.47	28.98	34.05	41.50	39.84	45.02
S_3	27.35	25.65	28.81	37.72	35.15	40.03
S.Em ±			0.59			1.19
CD (P = 0.05)			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)						
	G_1	G_2		G_1	G_2	
S_1F_1	37.47	32.58		51.02	45.97	
S_1F_2	34.82	31.35		46.67	43.25	
S_1F_3	40.55	35.95		49.32	49.37	
S_2F_1	31.82	29.12		43.27	40.69	
S_2F_2	30.69	27.27		41.27	38.42	
S_2F_3	35.37	32.72		46.65	43.39	
S_3F_1	28.17	26.52		39.07	36.32	
S_3F_2	26.35	24.95		36.30	34.00	
S_3F_3	29.15	28.47		41.17	38.90	
S.Em ±		0.83			1.68	
CD (P = 0.05)		NS			NS	
CV (%)		4.62			6.86	

NS = Non-significant

was in spacing S_3 at 30-45 days and 46-60 days (27.27 and 37.64 dm^2 day respectively).

Fertilizer level F_3 recorded significantly higher LAD at 30-45 days and 46-60 days (33.70 and 44.80 dm^2 day respectively). This was followed by fertilizers level F_1 at 30-45 days and 46-60 days (30.95 and 42.75 dm^2 day respectively). Significantly lowest LAD was in fertilizer level F_2 at 30-45 days and 46-60 days (29.24 and 39.98 dm^2 day respectively).

Marked differences were observed in LAD at 30-45 days to interaction of genotypes x spacings and was non-significant at 45-60 days. Significant variation in LAD was not observed to interaction of genotypes x fertilizer levels, fertilizer levels x spacing and genotypes x spacings x fertilizer levels (Table 4.6a).

Interaction of G_1S_1 recorded significantly higher LAD at 30-45 days (37.61 dm^2 day). Interactions G_2S_2 and G_1S_2 at 30-45 days (33.29 and 32.63 dm^2 day respectively) were at par. Significantly lower LAD was in G_2S_3 and G_1S_3 interaction at 30-45 days (26.65 and 27.89 dm^2 day respectively) which were on par.

4.1.7 Stem girth

The data on stem girth at 30, 45, 60 DAS and at harvest as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.7 and 4.7a.

Significant variation in stem girth was observed among genotypes at all stages of plant growth (Table 4.7). Significantly higher stem girth was in Arka Komal (G_1) at 30, 45, 60 DAS and at harvest (0.38, 0.51, 0.61 and 0.63 cm respectively) over the Burpee Stringless (G_2)

Table 4.7 : Stem girth (cm) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

	Days after sowing			
Treatments	30	45	60	At harvest
Genotypes (G)				
G_1	0.38	0.51	0.61	0.63
G_2	0.36	0.44	0.57	0.60
S. Em ±	0.003	0.004	0.004	0.003
CD (P = 0.05)	0.008	0.011	0.011	0.009
Sapcings (S)				
S_1	0.34	0.43	0.55	0.58
S_2	0.37	0.46	0.58	0.61
S_3	0.39	0.53	0.64	0.66
S. Em ±	0.004	0.005	0.005	0.004
CD (P = 0.05)	0.010	0.013	0.013	0.011
Fertilizer levels (F)				
F_1	0.37	0.48	0.59	0.62
F_2	0.35	0.46	0.56	0.60
F_3	0.39	0.50	0.62	0.64
S. Em ±	0.004	0.005	0.007	0.004
CD (P = 0.05)	0.010	0.013	0.019	0.011
CV. (%)	4.22	4.09	3.42	2.73

Table 4.7a : Stem girth (cm) at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

	DAYS AFTER SOWING											
Treatments	30			45			60			At harvest		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	0.35	0.34		0.47	0.40		0.56	0.53		0.58	0.57	
S_2	0.38	0.37		0.50	0.42		0.60	0.56		0.63	0.60	
S_3	0.40	0.39		0.57	0.50		0.66	0.62		0.68	0.64	
S.Em ±		0.01			0.01			0.01			0.01	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)												
F_1	0.38	0.36		0.57	0.44		0.61	0.57		0.63	0.60	
F_2	0.36	0.35		0.49	0.42		0.58	0.54		0.61	0.59	
F_3	0.39	0.38		0.54	0.46		0.63	0.60		0.66	0.63	
S.Em ±		0.01			0.01			0.01			0.01	
CD (P = 0.05)		NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.34	0.33	0.36	0.43	0.42	0.45	0.54	0.53	0.57	0.57	0.56	0.60
S_2	0.38	0.36	0.39	0.46	0.44	0.49	0.58	0.56	0.60	0.61	0.59	0.63
S_3	0.40	0.37	0.41	0.53	0.51	0.56	0.64	0.60	0.68	0.66	0.64	0.69
S.Em ±			0.01			0.01			0.01			0.01
CD (P = 0.05)			NS			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	0.36	0.33		0.47	0.40		0.56	0.52		0.58	0.57	
S_1F_2	0.34	0.32		0.45	0.38		0.55	0.51		0.57	0.56	
S_1F_3	0.37	0.35		0.49	0.41		0.58	0.55		0.60	0.59	
S_2F_1	0.38	0.37		0.50	0.42		0.60	0.56		0.62	0.60	
S_2F_2	0.37	0.35		0.47	0.40		0.58	0.55		0.61	0.59	
S_2F_3	0.39	0.38		0.53	0.45		0.62	0.59		0.65	0.61	
S_3F_1	0.41	0.39		0.57	0.50		0.65	0.63		0.69	0.64	
S_3F_2	0.38	0.36		0.54	0.48		0.63	0.57		0.65	0.63	
S_3F_3	0.42	0.41		0.60	0.52		0.69	0.67		0.72	0.67	
S.Em ±		0.01			0.01			0.00			0.01	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		4.62			4.09			3.42			2.73	

NS = Non-significant

at 30, 45, 60 DAS and at harvest (0.36, 0.44, 0.57 and 0.60 cm respectively).

Significantly higher stem girth was in spacing S_3 at 30, 45, 60 DAS and at harvest (0.39, 0.53, 0.64 and 0.66 cm respectively) followed by spacing S_2 at 30, 45, 60 DAS and at harvest (0.37, 0.46, 0.58 and 0.61 cm respectively) and the differences among them being significant. Spacing S_1 recorded significantly lowest stem girth at 30, 45, 60 DAS and at harvest (0.34, 0.43, 0.55 and 0.58 cm respectively).

Fertilizer level F_3 recorded significantly higher stem girth at 30, 45, 60 DAS and at harvest (0.39, 0.50, 0.62 and 0.64 cm respectively). This was followed by fertilizer level F_1 at 30, 45, 60 DAS and at harvest (0.37, 0.48, 0.58 and 0.61 cm respectively). Significantly lower stem girth was in fertilizer level F_2 at 30, 45, 60 DAS and at harvest (0.35, 0.46, 0.56 and 0.60 cm respectively).

Significant variation in stem girth was not observed due to interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizers levels (Table 4.7a).

4.1.8 Plant spread (North-South)

The data on plant spread in North-South at 30, 45 and 60 DAS as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.8 and 4.8a.

Plant spread in North-South direction showed significant difference among genotypes at 30 and 45 DAS and it was non-significant at 60 DAS. AT 30 and 45 DAS Arka Komal (G_1) showed significantly higher plant spread in North-South (16.00 and 19.08 cm respectively) over the Burpee Stringless (G_2) (14.76 and 17.68 cm respectively).

Table 4.8 : Spread of plant (cm) in North -South dirction at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

Treatments	Days after sowing 30	45	60
Genotypes (G)			
G_1	16.00	19.08	22.05
G_2	14.76	17.98	21.54
S. Em ±	0.26	0.28	0.30
CD (P = 0.05)	0.73	0.78	NS
Sapcings (S)			
S_1	14.72	18.09	20.91
S_2	15.41	18.62	21.77
S_3	16.02	18.89	22.77
S. Em ±	0.32	0.35	0.37
CD (P = 0.05)	0.89	NS	1.03
Fertilizer levels (F)			
F_1	15.59	18.75	21.81
F_2	14.62	17.91	21.21
F_3	15.94	18.93	22.36
S. Em ±	0.32	0.35	0.37
CD (P = 0.05)	0.89	NS	NS
CV. (%)	8.86	7.92	7.22

NS = Non -significant

Table 4.8a : Spread of plant (cm) in North-South direction at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

	DAYS AFTER SOWING								
	30			45			60		
	G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)									
S_1	15.51	13.93		18.54	17.64		20.85	20.37	
S_2	15.93	14.89		19.17	17.87		22.08	21.73	
S_3	16.57	15.48		19.52	19.08		23.21	22.33	
S.Em ±		0.45			0.49			0.52	
CD (P = 0.05)		NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)									
F_1	16.26	14.63		19.24	18.26		22.10	21.51	
F_2	15.23	14.01		18.63	17.19		21.49	20.94	
F_3	16.52	15.36		19.37	18.49		22.54	22.17	
S.Em ±		0.45			0.49			0.52	
CD (P = 0.05)		NS			NS			NS	
Fertilizer levels (F) x Spacings (S)									
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	14.84	14.16	15.15	18.20	17.65	18.41	20.46	20.18	21.48
S_2	15.57	14.70	15.95	18.91	17.87	19.08	21.93	21.42	22.37
S_3	16.36	14.99	16.71	19.13	18.22	19.29	23.03	22.04	23.22
S.Em ±			0.56			0.60			0.64
CD (P = 0.05)			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)									
	G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	15.63	14.06		18.72	17.68		20.73	20.20	
S_1F_2	15.17	13.16		18.09	17.20		20.47	19.89	
S_1F_3	15.74	14.56		18.80	18.03		21.35	21.62	
S_2F_1	16.22	14.92		19.31	18.51		22.09	21.78	
S_2F_2	15.18	14.24		18.75	17.00		21.59	21.25	
S_2F_3	16.38	15.51		19.47	18.70		22.57	22.16	
S_3F_1	16.92	15.80		19.68	18.58		23.52	22.55	
S_3F_2	15.35	14.63		19.05	17.38		22.40	21.69	
S_3F_3	17.43	16.00		19.84	18.74		23.71	22.74	
S.Em ±		0.79			0.85			0.91	
CD (P = 0.05)		NS			NS			NS	
CV (%)		8.86			7.92			7.22	

NS = Non-significant

Plant spread in North-South direction showed significant variation due to various spacings at 30 and 60 DAS and was at par at 45 DAS. At 30 DAS, significantly higher plant spread in North-South (16.02 cm) was in spacing S_3 over the spacing S_1 (14.72 cm) but, was on par with spacing S_2 (15.41 cm). Similar trend was observed at 60 DAS (Table 4.8).

Plant spread in North-South direction varied significantly due to various fertilizer levels at 30 DAS and was at par at 45 and 60 DAS. Fertilizer level F_3 recorded significantly higher plant spread in North-South (15.94 cm) at 30 DAS over the fertilizer level F_2 (14.62 cm). Fertilizer level F_3 and F_1 were at par.

Plant spread did not differs significantly to interactions of genotypes x spacings, genotypes x fertilizers, fertilizer x spacings and genotypes x spacings x fertilizer levels (Table 4.8a).

4.1.9 Plant Spread (East-West)

The data on plant spread in East-West at 30, 45 and 60 DAS as affected by genotypes, spacing and fertilizer levels and their interactions are presented in Tables 4.9 and 4.9a.

Plant spread in East-West direction showed significant difference among genotypes at 30 and 60 DAS and it was non-significant at 45 DAS. Arka Komal (G_1) recorded significantly higher spread of plant in East-West at 30 and 60 DAS (15.74 and 23.68 cm respectively) compared to Burpee Stringless (G_2) at 30 and 60 DAS (14.97 and 22.32 cm respectively).

At 30 DAS plant spread in East-West direction was higher in spacing S_3 (15.86 cm) which was on par with spacing S_2 (15.35 cm) and lowest in spacing S_1 (14.88 cm). Significantly higher plant spread in East-West at 45 DAS was in spacing S_3 (18.34) and lowest in spacing S_1 at 45 DAS (17.05)

Table 4.9 : Spread of plant (cm) in East -West direction at various stages of plant growth as affected by genotypes, spacings and fertilizer levels in french bean

Treatments	Days after sowing 30	45	60
Genotypes (G)			
G_1	15.74	17.95	23.68
G_2	14.97	17.35	22.32
S. Em ±	0.16	0.23	0.24
CD (P = 0.05)	0.46	NS	0.67
Sapcings (S)			
S_1	14.88	17.05	21.84
S_2	15.35	17.55	23.02
S_3	15.86	18.34	24.13
S. Em ±	0.20	0.28	0.30
CD (P = 0.05)	0.56	0.78	0.82
Fertilizer levels (F)			
F_1	15.52	17.65	23.18
F_2	14.75	17.04	22.14
F_3	15.81	18.25	23.68
S. Em ±	0.20	0.28	0.30
CD (P = 0.05)	0.56	0.78	0.82
CV. (%)	5.57	6.76	5.47

NS = Non-significant

Table 4.9a : Spread of plant (cm) in East -West direction at various stages of plant growth as affected by genotypes, spacings and fertilizer levels interactions in french bean

Treatments	DAYS AFTER SOWING								
	30			45			60		
	G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)									
S_1	15.25	14.50		17.27	16.84		22.69	20.99	
S_2	15.61	15.09		17.83	17.27		23.64	22.40	
S_3	16.37	15.34		18.75	17.98		24.71	23.55	
S.Em ±		0.28			0.40			0.42	
CD (P = 0.05)		NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)									
F_1	15.89	15.14		17.91	17.39		24.02	22.34	
F_2	15.04	14.46		17.28	16.82		22.81	21.48	
F_3	16.30	15.32		18.66	17.83		24.22	23.13	
S.Em ±		0.28			0.40			0.42	
CD (P = 0.05)		NS			NS			NS	
Fertilizer levels (F) x Spacings (S)									
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	14.97	14.53	15.10	16.97	16.76	17.43	21.86	21.11	22.56
S_2	15.23	14.67	15.85	17.63	16.96	18.06	23.06	22.34	23.66
S_3	16.05	15.04	16.48	18.34	17.42	19.25	24.62	22.97	24.81
S.Em ±			0.35			0.49			0.51
CD (P = 0.05)			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)									
	G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	15.30	14.65		17.09	16.84		22.79	20.92	
S_1F_2	14.98	14.13		16.99	16.53		21.99	20.22	
S_1F_3	15.48	14.72		17.72	17.14		23.30	21.83	
S_2F_1	15.73	15.32		17.99	17.28		23.98	22.15	
S_2F_2	14.76	14.58		17.12	16.79		22.94	21.75	
S_2F_3	16.33	15.38		18.38	17.73		24.00	23.33	
S_3F_1	16.64	15.47		18.66	18.04		25.30	23.95	
S_3F_2	15.38	14.69		17.72	17.13		23.48	22.47	
S_3F_3	17.09	15.86		19.87	18.63		25.37	24.24	
S.Em ±		0.49			0.69			0.73	
CD (P = 0.05)		NS			NS			NS	
CV (%)		5.57			6.76			5.48	

NS = Non-significant

which was on par with spacing S_2 (17.55 cm). At 60 DAS, significantly higher spread of plant in East-West was in spacing S_3 (24.13 cm) over the spacing S_2 (23.02) and lowest plant spread at 60 DAS was in spacing S_1 (21.84 cm).

Highest plant spread in East-West direction was in fertilizer level F_3 at 30 DAS (15.81 cm) which was on par with fertilizer level F_1 (15.52 cm) and lowest in fertilizer level F_2 (14.75 cm). Similar trend was observed at 60 DAS (Table 4.9). At 45 DAS, higher spread of plant in East-West direction was in fertilizer level F_3 (18.25 cm) which was on par with fertilizer level F_1 (17.65 cm) and lowest was in fertilizer level F_2 (17.04 cm) which was on par with fertilizer level F_1.

Interactions of genotypes x spacings, genotypes x fertilizers levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not differ significantly in plant spread in East-West direction (Table 4.9a).

4.1.10 Dry matter accumulation and distribution in different plant parts at 60 DAS.

The data on dry matter accumulation and distribution in stem leaf, pod, root and total at 60 DAS in relation to genetypes, spacings and fertilizer levels and their interactions are presented in Tables 4.10 and 4.10a and Fig. 1.

4.1.10.1 Dry matter accumulation in stem

Dry matter accumulation in stem varied significantly among geno types at 60 DAS. Significantly higher dry matter accumulation in stem (4.51 g / plant) at 60 DAS was in Arka Komal (G_1) over the Burpee Stringless (G_2) (4.13 g/plant).

Significantly higher dry matter accumulation in stem at 60 DAS was in spacing S_3 (4.57 g/plant) followed by spacing S_2 (4.36 g/plant). The lowest was in spacing S_1 (4.03 g/plant).

Fertilizer level F_3 at 60 DAS recorded highest dry matter accumulation in stem (4.48 g/plant) and was on par with fertilizer level F_1 (4.32 g/plant). The lowest was in fertilizer level F_2 (4.16 g/plant)

Dry matter accumulation in stem did not differ significantly to interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and geno types x spacings x fertilizer levels (Table 4.10a).

4.1.10.2 Dry matter accumulation in leaf

Arka Komal(G_1) recorded significantly higher dry matter accumulation in leaf (6.49 g/plant) at 60 DAS over the Burpee Stringless (G_2) (6.04 g/plant).

Significantly higher dry matter accumulation of leaf (7.11 g/plant) was in spacing S_3 at 60 DAS followed by the spacing S_2 (6.04 g/plant). The lowest (5.65 g/plant) was in spacing S_1 at 60 DAS.

At 60 DAS fertilizer level F_3 produced significantly higher dry matter accumulation in leaf (6.53 g/plant). The lowest was in fertilizer level F_2 (6.02 g/plant) at 60 DAS which was on par with fertilizer level F_1 (6.25 g/plant).

Dry matter accumulation in leaf at 60 DAS varied significantly to the interaction of genotypes and spacings. Dry matter accumulation in leaf was significantly highest in the interaction of G_1S_3 (7.58 g/plant) followed by G_2 S_3 (6.64 g/plant). Dry matter accumulation in leaf was significantly lowest in the combination of G_2 S_1 (5.52 g/plant) and was on par with G_1 S_1 (5.79 g/plant).

Interaction of genotypes x fertilizer level, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not influence significantly the dry matter accumulation in leaf (Table 4.10a).

4.1.10.3 Dry matter accumulation in pod

Arka Komal (G_1) produced significantly higher dry matter accumulation in pod (13.12 g/plant) over the Burpee Stringless (G_2) (11.37 g/plant).

Spacing S_3 produced significantly higher accumulation of dry matter in pod (13.23 g/plant) over the other spacings. Spacing S_2 produced significantly higher dry matter accumulation in pod (12.16 g/plant) than spacing S_1 (11.34 g/plant) and the later recorded the lowest.

At 60 DAS fertilizer level F_3 produced highest dry matter accumulation in pod (12.64 g/plant) which was on par with fertilizer level F_1 (12.38 g/plant). The lowest at 60 DAS was in fertilizer level F_2 (11.70 g/plant).

Dry matter accumulation at 60 DAS in pod did not differ significantly to interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels (Table 4.10a).

4.1.10.4 Dry matter accumulation in root

Arka Komal (G_1) at 60 DAS produced significantly higher dry matter accumulation in root (1.50 g/plant) over the Burpee Stringless (G_2) (1.43 g/plant).

Table 4.10 : Dry matter accumulation and distribution in different plant parts of french bean in relation to genotypes, spacings and fertilizer levels at 60 DAS

	Dry matter accumulation and distribution (g/plant)				
Treatments	Stem	Leaf	Pod	Root	Total
Genotypes (G)					
G_1	4.51	6.49	13.12	1.50	25.62
G_2	4.13	6.04	11.37	1.43	22.97
S. Em ±	0.05	0.07	0.18	0.02	0.22
CD (P = 0.05)	0.14	0.19	0.51	0.05	0.60
Sapcings (S)					
S_1	4.03	5.65	11.34	1.29	22.31
S_2	4.36	6.04	12.16	1.50	24.06
S_3	4.57	7.11	13.23	1.61	26.52
S. Em ±	0.06	0.09	0.22	0.02	0.28
CD (P = 0.05)	0.17	0.23	0.62	0.06	0.74
Fertilizer levels (F)					
F_1	4.32	6.25	12.38	1.47	24.42
F_2	4.16	6.02	11.70	1.38	23.26
F_3	4.48	6.53	12.64	1.55	25.20
S. Em ±	0.06	0.07	0.22	0.02	0.27
CD (P = 0.05)	0.17	0.24	0.62	0.06	0.74
CV. (%)	5.90	5.80	7.80	6.81	4.67

Table 4.10a : Dry matter accumulation and distribution in different plant parts of french bean in relation to interactions of genotypes spacings and fertilizer levels at 60 DAS

Treatments	Dry matter accumulation and distribution (g/plant)									
	Stem		Leaf		Pod		Root		Total	
	G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2
Genotypes (G) x Spacings (S)										
S_1	4.22	3.83	5.79	5.52	11.87	10.81	1.36	1.23	23.24	21.40
S_2	4.66	4.16	6.10	5.98	13.04	11.27	1.51	1.48	25.26	22.89
S_3	4.73	4.41	7.58	6.64	14.45	12.01	1.65	1.57	29.31	24.64
S.Em ±		0.80		0.12		0.32		0.03		0.38
CD (P = 0.05)		*NS*		*0.34*		*NS*		NS		NS
Genotypes (G) x Fertilizer levels (F)										
F_1	4.52	4.11	6.50	6.01	13.37	11.40	1.51	1.43	25.67	22.95
F_2	4.30	4.02	6.21	5.82	12.35	11.05	1.43	1.34	24.41	22.24
F_3	4.70	4.27	6.76	6.31	13.64	11.64	1.58	1.52	26.72	23.74
S.Em ±		0.01		0.12		0.32		0.03		0.38
CD (P = 0.05)		NS		NS		NS		NS		NS

Fertilizer levels (F) x Spacings (S)	Stem F_1	Stem F_2	Stem F_3	Leaf F_1	Leaf F_2	Leaf F_3	Pod F_1	Pod F_2	Pod F_3	Root F_1	Root F_2	Root F_3	Total F_1	Total F_2	Total F_3
S_1	4.00	3.85	4.23	5.70	5.38	5.88	11.32	10.92	11.78	1.26	1.20	1.41	22.29	21.35	23.31
S_2	4.40	4.22	4.47	6.08	5.88	6.15	12.15	11.78	12.54	1.52	1.41	1.56	24.15	23.29	24.78
S_3	4.55	4.42	4.75	6.98	6.78	7.57	13.68	12.41	13.60	1.61	1.54	1.68	26.49	25.34	27.60
S.Em ±			0.10			0.15			0.39			0.04			0.46
CD (P = 0.05)			NS			NS			NS			NS			NS

Genotypes (G) x Spacings (S) x Fertilizer levels (F)	Stem G_1	Stem G_2	Leaf G_1	Leaf G_2	Pod G_1	Pod G_2	Root G_1	Root G_2	Total G_1	Total G_2
S_1F_1	4.20	3.80	5.87	5.53	11.80	10.85	1.35	1.19	23.21	21.37
S_1F_2	4.00	3.70	5.50	5.27	11.25	10.59	1.25	1.15	22.00	20.70
S_1F_3	4.47	4.00	6.00	5.77	12.56	11.00	1.47	1.35	24.50	22.12
S_2F_1	4.63	4.17	6.17	6.00	13.00	11.31	1.53	1.51	25.33	22.97
S_2F_2	4.37	4.07	5.90	5.87	12.43	11.13	1.44	1.38	24.13	22.45
S_2F_3	4.70	4.23	6.23	6.07	13.69	11.39	1.56	1.56	26.31	23.25
S_3F_1	4.73	4.37	7.47	6.50	13.38	12.06	1.64	1.59	28.47	24.51
S_3F_2	4.53	4.30	7.23	6.33	14.67	11.45	1.59	1.49	27.10	23.57
S_3F_3	4.93	4.57	8.03	7.10	25.37	12.53	1.72	1.65	29.35	25.85
S.Em ±		0.15		0.21		0.55		0.06		0.65
CD (P = 0.05)		NS		NS		NS		NS		NS
CV (%)		5.90		5.80		7.80		3.20		9.80

NS = Non-significant

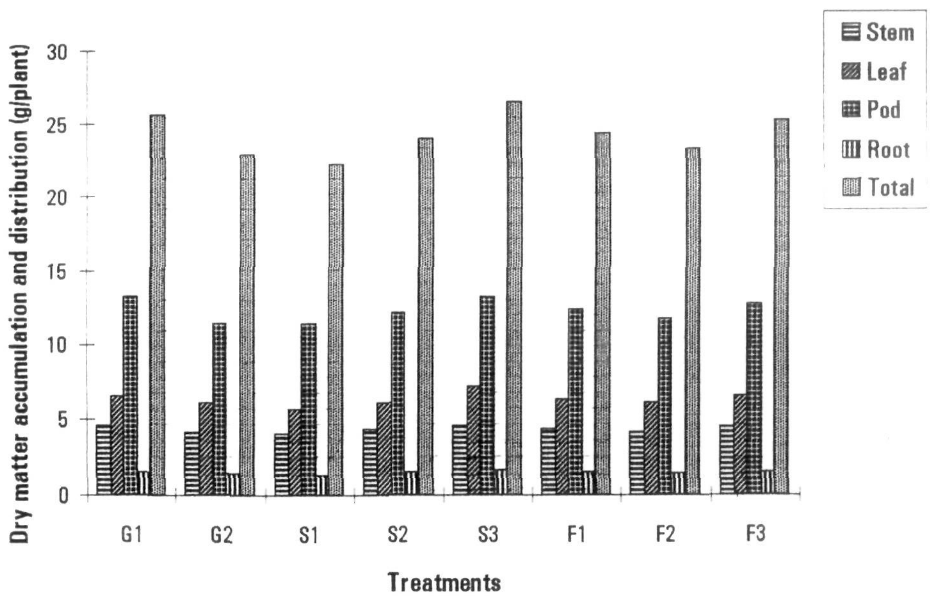

Fig. 1. Dry matter accumulation and distribution in different plant parts at 60 DAS as influenced by genotypes, spacings and fertilizer levels

At 60 DAS significantly higher dry matter accumulation in root was in spacing S_3 (1.61 g/plant) followed by spacing S_2 (1.50 g/plant). Significantly lowest dry matter accumulation in root at 60 DAS was in spacing S_1 (1.29 g/plant).

Fertilizer level F_3 produced significantly higher dry matter accumulation at 60 DAS in root (1.55 g/plant) followed by fertilizer level F_1 (1.47 g/plant). Significantly lowest dry matter accumulation in root at 60 DAS was in fertilizer level F_2 (1.38 g/plant).

Dry matter accumulation in root at 60 DAS was not significantly influenced by interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels (Table 4.10a).

4.1.10.5 Total dry matter accumulation.

Arka Komal (G_1) produced significantly higher total dry matter accumulation in plant (25.62 g/plant) at 60 DAS on Burpee Stringless (22.97 g/plant).

Total dry matter accumulation was significantly higher in spacing S_3 (26.52 g/plant) at 60 DAS followed by spacing S_2 (24.07 g/plant). Significantly lowest total dry matter accumulation was in spacing S_1 (22.31 g/plant) at 60 DAS.

Fertilizer level F_3 produced significantly higher total dry matter accumulation (25.20 g/plant) at 60 DAS followed by fertilizer level F_1 (24.42 g) and the differences among them being significant. Significantly lowest total dry matter accumulation in plant at 60 DAS was in fertilizer level F_2 (23.26 g/plant).

Interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not influence significantly the total dry matter accumulation in plant at 60 DAS (Table 4.10a).

4.1.11 Dry matter accumulation and distribution in plant parts at harvest.

The data on dry matter accumulation and distribution in stem leaf, pod, root and total dry matter at harvest in relation to genotypes, spacings and fertilizer levels and their interactions has been furnished in Tables 4.11 and 4.11 a and Fig. 2.

Arka Komal produced significantly higher dry matter accumulation in stem (5.22 g/plant) than Burpee Stringless. (4.65 g/plant) at harvest.

Spacing S_3 produced significantly higher dry matter accumulation in stem (5.40 g/plant) than spacing S_2 and S_1. Spacing S_2 produced significantly higher dry matter in stem (4.87 g/plant) than spacing S_1 (4.54 g/plant) and the latter recorded the lowest.

Fertilizer level F_3 produced significantly higher dry matter in stem (5.23 g/plant) at harvest than fertilizer levels F_1 and F_2. Fertilizer level F_1 produced significantly higher drymatter accumulation in stem (4.93 g/plant) than fertilizer level F_2 (4.65 g/plant) and the latter recorded the lowest.

Dry matter accumulation in stem was not significantly influenced by the interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels. (Table 4.11 a).

4.1.11.2 Dry matter accumulation in leaf

Dry matter accumulation in leaf at harvest was significantly higher in Arka Komal (4.69 g/plant) than Burpee-Stringless (4.27 g/plant).

Significantly higher dry matter accumulation in leaf at harvest was in spacing S_3 (5.31 g/plant) followed by spacing S_2 (4.23 g/plant) at harvest, and the differences among them being significant. Significantly lowest dry matter accumulation in leaf at harvest was in spacing S_1 (3.87 g/plant).

At harvest fertilizer level F_3 produced significantly higher dry matter accumulation in leaf (4.73 g/plant) than fertilizer level F_1 and F_2 (4.48 and 4.22 g/plant). Significantly lowest dry matter accumulation in leaf at harvest was in fertilizer level F_2 (4.22 g/plant).

Interaction combination of G_1S_3 produced significantly highest dry matter accumulation in leaves (5.78 g/plant) at harvest than other interactions. This was followed by interaction G_2S_3 (4.84 g/plant). The interaction G_1S_2 and G_2S_2 (4.30 and 4.21 g/plant respectively) were at par. Interaction of G_2S_1 produced significantly lowest dry matter accumulation in leaves (3.74 g/plant) at harvest which was on par with combination of G_1S_1 at harvest (3.99 g/plant).

Dry matter accumulation in leaf at harvest did not differ significantly to the other interactions of genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels (Table 4.11a).

4.1.11.3 Dry matter accumulation in pod

Arka Komal (G_1) produced significantly higher dry matter accumulation in pod (15.32 g/plant) at harvest compared to Burpee Stringless (G_2) (13.57 g/plant)

Dry matter accumulation in pod at harvest was significantly higher in spacing S_3 (15.37 g/plant) followed by spacing S_2 (14.41 g/plant) and the differences among them being significant. Significantly lowest drymatter accumulation in pod at harvest was in spacing S_1 (13.55 g/plant).

Fertilizer levels F_3 and F_1 were at par in dry matter accumulation in pod (14.86 and 14.55 g/plant respectively). However fertilizer level F_3 produced significantly higher dry matter of pod at harvest than fertilizer level F_2 (13.92 g/plant) and the latter recorded the lowest.

Dry matter accumulation in pod at harvest was not significantly affected by the interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels at harvest (Table 4.11a).

4.1.11.4 Dry matter accumulation in root

Arka Komal (G_1) at harvest produced significantly higher dry matter accumulation in root (1.84 g/plant) than Burpee Stringless (G_2) (1.76 g/plant).

Significantly higher dry matter accumulation in root at harvest (1.95 g/plant) was in spacing S_3 followed by spacing S_2 (1.83 g/plant) and the differences among them being significant. Significantly lowest dry matter accumulation in root at harvest was in spacings S_1 (1.62 g/plant).

Fertilizer level F_3 produced significantly higher dry matter accumulation in root at harvest (1.88 g/plant) followed by fertilizer level F_1 (1.80 g/plant) and the differences among them being significant. Significantly lowest total dry matter accumulation in root at harvest was in fertilizer level F_2 (1.72 g/plant).

Table 4.11 : Dry matter accumulation and distribution in different plant parts of french bean at harvest in relation to genotypes, spacings and fertilizer levels

Treatments	Dry matter accumulation and distribution (g/plant)				
	Stem	Leaf	Pod	Root	Total
Genotypes (G)					
G_1	5.22	4.69	15.32	1.84	27.07
G_2	4.65	4.27	13.57	1.76	24.25
S. Em ±	0.05	0.07	0.20	0.02	0.22
CD (P = 0.05)	0.14	0.19	0.55	0.05	0.60
Sapcings (S)					
S_1	4.54	3.87	13.55	1.62	23.58
S_2	4.87	4.23	14.41	1.83	25.34
S_3	5.40	5.31	15.37	1.95	28.03
S. Em ±	0.06	0.08	0.24	0.02	0.26
CD (P = 0.05)	0.17	0.23	0.68	0.06	0.73
Fertilizer levels (F)					
F_1	4.93	4.48	14.55	1.80	25.76
F_2	4.65	4.22	13.92	1.72	24.51
F_3	5.23	4.73	14.86	1.88	26.70
S. Em ±	0.06.	0.08	0.24	0.02	0.26
CD (P = 0.05)	0.17	0.23	0.68	0.06	0.73
CV. (%)	5.37	8.00	7.20	5.34	4.37

Table 4.11a : Dry matter accumulation and distribution in different plant parts of french bean in relation to interactions of genotypes spacings and fertilizer levels at harvest

Treatments	Dry matter accumulation and distribution (g/plant)														
	Stem			Leaf			Pod			Root			Total		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)															
S_1	4.82	4.27		3.99	3.74		1.69	1.55		24.61	22.58		23.24	21.40	
S_2	5.23	4.51		4.30	4.21		1.85	1.82		26.73	24.02		25.26	22.89	
S_3	5.61	5.19		5.78	4.84		1.99	1.92		29.89	26.16		29.31	24.64	
S.Em ±		0.09			0.35			0.03			0.37			0.38	
CD (P = 0.05)		NS			0.33			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)															
F_1	5.25	4.61		4.70	4.27		15.51	13.60		1.85	1.76		27.30	24.21	
F_2	4.88	4.43		4.41	4.02		14.58	13.26		1.76	1.68		25.64	23.40	
F_3	5.53	4.92		4.96	4.51		15.87	13.84		1.92	1.84		28.28	25.17	
S.Em ±		0.09			0.12			0.35			0.03			0.37	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)															
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	4.53	4.35	4.75	3.93	3.58	4.08	13.54	13.13	13.99	1.61	1.52	1.72	23.57	20.62	24.58
S_2	4.85	4.65	5.12	4.33	4.08	4.35	14.47	14.01	14.75	1.85	1.75	1.90	25.51	24.49	26.12
S_3	5.42	4.97	5.82	5.18	4.98	5.77	15.66	14.62	15.82	1.95	1.88	2.02	28.19	26.45	29.42
S.Em ±			0.11			0.15			0.42			0.04			0.46
CD (P = 0.05)			NS			NS			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)															
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	4.83	4.23		4.07	3.80		14.03	13.05		1.69	1.53		24.62	22.52	
S_1F_2	4.57	4.13		3.70	3.47		13.48	12.77		1.56	1.49		23.33	21.92	
S_1F_3	5.07	4.43		4.20	3.97		14.79	13.20		1.81	1.63		25.87	23.20	
S_2F_1	5.23	4.47		4.37	4.30		15.43	13.51		1.87	1.84		26.90	24.11	
S_2F_2	4.97	4.33		4.10	4.07		14.56	13.36		1.78	1.72		25.53	23.45	
S_2F_3	5.50	4.73		4.43	4.27		15.92	13.59		1.90	1.90		27.75	24.49	
S_3F_1	5.70	5.13		5.67	4.70		17.07	14.26		1.98	1.93		30.37	26.02	
S_3F_2	5.10	4.83		5.43	4.53		15.61	13.64		1.93	1.83		28.07	24.83	
S_3F_3	6.03	5.60		6.23	5.30		16.90	14.73		2.06	1.99		31.22	27.63	
S.Em ±		0.02			0.21			0.60			0.05			0.64	
CD (P = 0.05)		NS			NS			NS			NS			NS	
CV (%)		5.37			8.00			7.20			5.34			4.37	

NS – Non significant

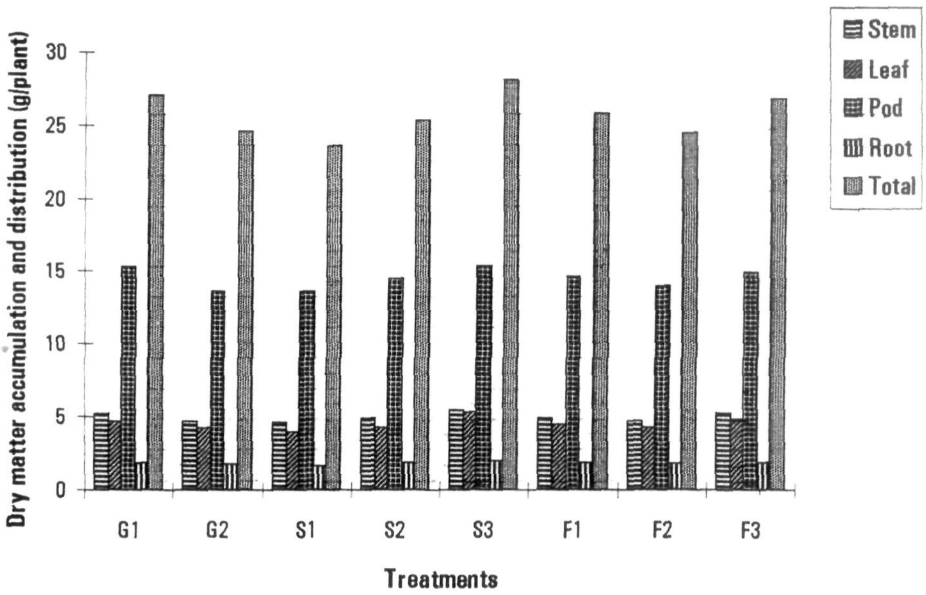

Fig. 2. Dry matter accumulation and distribution in different plant parts at harvest as influenced by genotypes, spacings and fertilizer levels

Dry matter accumulation in root at harvest did not differ significantly to the interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels (Table 4.11a)

4.1.11.5 Total dry matter accumulation

Significantly highest total dry matter accumulation at harvest was in Arka Komal (G_1) (27.07 g/plant) over the Burpee Stringless (G_2) (24.25 g/plant).

Significantly higher total dry matter accumulation at harvest was in spacing S_3 (28.03 g/plant) followed by spacing S_2 (25.34 g/plant) and the differences among them being significant. Significantly lowest total dry matter accumulation at harvest was in spacings (23.58 g/plant).

Fertilizer level F_3 at harvest produced significantly highest total dry matter accumulation (26.70 g/plant) followed by fertilizer level F_1 (25.76 g/plant) and the differences among them being significant. Significantly lowest total dry matter accumulation at harvest was in fertilizer level F_2 (24.51 g/plant).

Total dry matter accumulation did not differ significantly at harvest to the interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels.

4.2. Yield and Yield parameters.

4.2.1 Number of pods per plant

The data on number of pods per plant as affected by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.12 and 4.12 a and Fig. 3.

Significantly higher number of pods per plant (11.17) was in Arka Komal (G_1) over the Burpee Stringless (G_2) (10.23).

Significantly higher number of pods per plant were in spacing S_3 and S_2 (11.32 and 10.86 respectively) over the spacing S_1. Spacing S_1 recorded significantly lowest number of pods per plant (9.92).

In production of number of pods per plant fertilizer levels F_3 and F_1 (11.12 and 10.70 respectively) were at par and fertilizer level F_3 recorded significantly higher number of pods per plant than fertilizer level F_2. Fertilizer level F_2 recorded the lowest (10.29).

Number of pods per plant did not differ significantly to the interaction of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels (Table 4.12a).

4.2.2 Pod length

The data on pod length in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.12 and 4.12 a and Fig. 3.

Arka Komal produced significantly higher average pod length (14.75 cm) over the Burpee Stringless (G_2) (11.86 cm).

Significantly higher pod length (13.94 cm) was in spacing S_3 followed by spacing S_2 (13.20 cm) and the differences among them being significant. The lowest (12.77 cm) was in spacing S_1.

Highest pod length was in fertilizer level F_3 (13.62 cm) followed by fertilizer level F_1 (13.33 cm) which were at par. The lowest pod length was in fertilizer level F_2 (12.96 cm).

Table 4.12 : Number of pods per plant, length of pod, weight of pod and yield of pod in french bean in relation to genotypes, spacings and fertilizer levels

Treatments	Number of pods/plant	Length of pod (cm)	Weight of pod (g)	Pod yield (q/ha)
Genotypes (G)				
G_1	11.17	14.75	31.12	22.09
G_2	10.23	11.86	29.82	17.07
S. Em ±	0.14	0.14	0.75	0.22
CD (P = 0.05)	0.39	0.39	NS	0.62
Sapcings (S)				
S_1	9.92	12.77	27.80	21.39
S_2	10.86	13.20	30.34	19.88
S_3	11.32	13.94	33.27	17.48
S. Em ±	0.17	0.17	0.92	0.27
CD (P = 0.05)	0.48	0.48	2.56	0.76
Fertilizer levels (F)				
F_1	10.70	13.33	30.33	19.50
F_2	10.29	12.96	29.17	18.60
F_3	11.12	13.62	31.92	20.65
S. Em ±	0.17	0.17	0.92	0.27
CD (P = 0.05)	0.48	0.48	NS	0.76
CV. (%)	6.89	5.52	12.85	5.95

NS = Non-significant

Table 4.12a : Number of pods, length of pod, weight of pod and yield of pod in french bean in relation to interactions of genotypes spacings and fertilizer levels

Treatments	Number of pods/plant			Length of pod (cm)			Pod weight/plant (g)			Pod yield (q/ha)		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	10.36	9.48		14.18	11.36		28.33	27.28		23.63	19.14	
S_2	11.29	10.44		14.61	11.39		31.11	29.28		22.75	17.01	
S_3	11.86	11.86		15.45	12.42		33.93	36.61		19.90	0.39	
S.Em ±		0.25			0.24			1.30			0.37	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)												
F_1	11.16	10.24		14.73	11.92		31.12	29.54		21.94	17.07	
F_2	10.65	9.93		14.46	11.46		30.00	28.34		20.94	16.26	
F_3	11.70	10.54		15.04	12.19		32.24	31.58		23.40	17.89	
S.Em ±		0.25			0.24			1.30			0.39	
CD (P = 0.05)		NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	9.86	9.45	10.46	12.90	12.34	13.07	27.90	27.00	28.50	21.89	20.05	22.82
S_2	10.91	10.58	11.10	13.19	12.98	13.43	30.43	29.08	31.53	19.90	19.00	20.73
S_3	11.33	10.85	11.78	13.89	13.56	14.36	32.64	31.44	35.72	17.32	16.73	18.40
S.Em ±			0.30			0.30			1.60			0.48
CD (P = 0.05)			NS			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	10.31	9.41		14.20	11.50		28.59	27.22		23.36	19.22	
S_1F_2	9.78	9.11		14.00	10.68		27.49	26.54		22.72	17.39	
S_1F_3	11.00	9.92		14.33	11.80		28.93	28.07		24.82	20.82	
S_2F_1	11.36	10.46		14.60	11.78		31.11	29.75		22.80	16.92	
S_2F_2	10.85	10.31		14.43	11.53		29.96	28.19		21.42	16.60	
S_2F_3	11.65	10.56		14.80	12.06		32.26	30.80		23.94	17.52	
S_3F_1	11.80	10.86		15.40	12.39		33.65	31.65		19.54	15.06	
S_3F_2	11.33	10.36		14.96	12.17		32.58	30.31		18.68	14.79	
S_3F_3	12.44	11.12		16.00	12.72		35.55	35.88		21.45	15.34	
S.Em ±		0.43			0.42		16.90	2.26			0.67	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		6.89			5.52			12.85			5.95	

NS = Non-significant

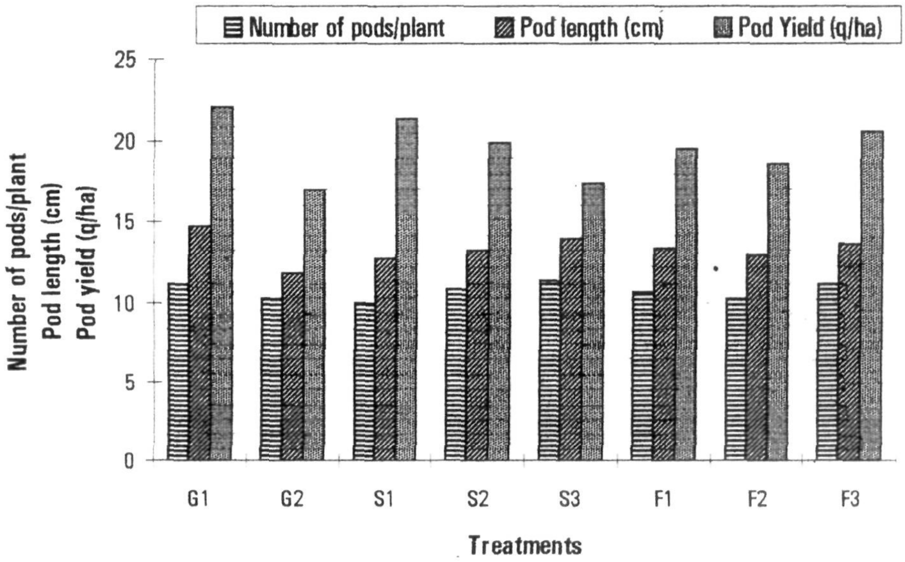

Fig. 3. Number of pods per plant, length of pod and yield of pod as influenced by genotypes, spacings and fertilizer levels

Interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not influence significantly the pod length (Table 4.12 a).

4.2.3 Weight of pod

The data on weight of pod in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.12 and 4.12a.

Weight of pod did not differ significantly among the genotypes (Table 4.12).

Significantly higher weight of pod (33.27 g/plant) was in spacing S_3. The lowest was in spacing S_1 (27.80 g/plant) and was on par with spacing S_2 (30.34 g/plant).

Weight of pod did not differ significantly due to various fertilizer levels (Table 4.12).

The interaction effects of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels had no significant effect on weight of pod (Table 4.12 a).

4.2.4 Pod yield per ha

The data on pod yield per ha in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.12 and 4.12a and Fig. 3.

Arka Komal (G_1) produced significantly higher pod yield per ha (22.09 q/ha) over the Burpee Stringless (G_2) (17.07 q/ha).

Significantly higher pod yield (21.39 q/ha) was in spacing S_1 over the spacings S_2 and S_3 (19.88 and 17.48 q/ha). Spacing S_2 produced significantly higher pod yield than S_3 and the latter recorded the lowest pod yield.

Fertilizer level F_3 produced significantly higher pod yield (20.65 q/ha) over the fertilizer F_1 and F_2. Fertilizer level F_1 recorded significantly higher pod yield (19.50 q/ha) than fertilizer level F_2 (18.60 q/ha) and the latter recorded the lowest.

Pod yield per ha did not differ significantly to the interactions of genotypes x spacings, genotypes x fertilizer levels, fertilizer levels x spacing and genotypes x spacings x fertilizer levels (Table 4.12 a).

4.2.5 Seeds per pod

The data on seeds per pod in relation to genotypes, spacings and fertilizer levels and their interaction are presented in Tables 4.13 and 4.13a.

Significantly higher seeds per pod (6.47) was in Arka Komal (G_1) over the Burpee Stringless (G_2) (5.38).

Spacing S_3 produced significantly higher seeds per pod (6.68) followed by spacing S_2 (5.88) and the differences among them being significant. The lowest (5.21) was in spacing S_1.

Application of fertilizer level F_3 produced significantly higher seed per pod (6.29) followed by fertilizer level F_1 (5.91). Significantly lowest (5.57) was in fertilizer level F_2.

Seeds per pod differed significantly to the interaction between genotypes and spacings. Significantly highest seeds per pod was in interaction of

Table 4.13 : Seeds per pod, seeds per plant and seed weight per plant of french bean in relation to genotypes, spacings and fertilizer levels

Treatments	Seeds per pod	Seeds per plant	Seed weight per plant (g)
Genotypes (G)			
G_1	6.47	52.20	22.45
G_2	5.38	46.75	20.33
S. Em ±	0.08	1.13	0.46
CD (P = 0.05)	0.23	3.14	1.27
Sapcings (S)			
S_1	5.21	45.58	19.32
S_2	5.88	47.96	21.45
S_3	6.68	53.45	23.40
S. Em ±	0.10	1.39	0.56
CD (P = 0.05)	0.28	3.85	1.55
Fertilizer levels (F)			
F_1	5.91	49.05	21.29
F_2	5.57	47.96	20.53
F_3	6.29	51.41	22.35
S. Em ±	0.10	1.39	0.56
CD (P = 0.05)	0.28	NS	NS
CV. (%)	7.17	11.90	11.13

NS = Non-significant

Table 4.13a : Seeds per pod, seeds per plant and seed weight per plant of french bean in relation to interactions of genotypes spacings and fertilizer levels

Treatments	Seeds per pod			Seeds per plant			Seed weight per plant (g)		
	G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)									
S_1	5.45	4.97		47.46	43.69		20.41	18.23	
S_2	6.50	5.26		53.06	45.72		22.27	20.63	
S_3	7.45	5.90		56.07	50.83		24.67	20.13	
S.Em ±		0.14			1.96			0.79	
CD (P = 0.05)		0.39			NS			NS	
Genotypes (G) x Fertilizer levels (F)									
F_1	6.41	5.40		51.58	46.51		22.27	20.31	
F_2	6.07	5.06		50.75	45.16		21.58	19.48	
F_3	6.92	5.67		54.26	48.57		23.50	21.20	
S.Em ±		0.14			1.96			0.79	
CD (P = 0.05)		NS			NS			NS	
Fertilizer levels (F) x Spacings (S)									
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	5.23	4.94	5.46	45.26	44.32	47.15	19.26	18.53	20.17
S_2	5.74	5.43	6.47	49.22	47.69	51.26	21.40	20.59	22.36
S_3	6.75	6.33	6.95	52.65	51.87	55.83	23.20	22.40	24.52
S.Em ±			0.17			2.40			0.97
CD (P = 0.05)			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)									
	G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	5.52	4.94		46.62	43.90		20.25	18.27	
S_1F_2	5.08	4.79		45.93	42.71		19.69	17.37	
S_1F_3	5.74	5.18		49.83	44.46		21.29	19.05	
S_2F_1	6.17	5.30		53.16	45.27		22.33	20.48	
S_2F_2	5.98	4.89		51.91	43.47		21.21	19.97	
S_2F_3	7.36	5.58		54.11	48.42		23.29	21.43	
S_3F_1	7.55	5.96		54.97	50.35		24.22	22.18	
S_3F_2	7.17	5.49		54.42	49.31		23.85	21.10	
S_3F_3	7.65	6.24		58.83	52.83		25.93	23.11	
S.Em ±		0.24			3.40			1.37	
CD (P = 0.05)		NS			NS			NS	
CV (%)		7.17			11.90			11.13	

NS = Non-significant

G_1S_1 (7.45) followed by G_1S_2 (6.50). Significantly higher seeds per pod was in combination of G_2S_3 (5.90) followed by G_1S_1 (5.45). Significantly lowest seeds per pod was in combination of G_2S_1 (4.97). The interaction effect of genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels had no significantly effect on the seeds per pod. (Table 4.13 a).

4.2.6 Seeds per plant.

The data on seeds per plant in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.13 and 4.13a.

Arka Komal (G_1) produced significantly higher seeds per plant (52.20) over the Burpee Stringless (G_2) (46.75).

Significantly higher seeds per plant (53.45) was in spacing S_3. Significantly lowest (45.58) was in spacing S_1 and was on par with spacing S_2 (47.96).

Seeds per plant did not differ significantly due to various fertilizer levels (Table 4.13). Seeds per plant did not differ significantly to genotypes, spacings and fertilizer levels interactions (Table 4.13a).

4.2.7 Seed weight per plant

The data on seed weight per plant in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.13 and 4.13a.

Significantly higher seed weight per plant (22.45 g) was in Arka Komal (G_1) over the Burpee Stringless (G_2) (20.33 g).

Spacing S_3 recorded significantly higher seed weight per plant (23.40 g) over the spacings S_2 and S_1 (21.45 and 19.32 g) Spacing S_2 recorded significantly higher seed weight per plant than S_1.

Seed weight per plant was not significantly influenced by various fertilizer levels (Table 4.13).

Seed weight per plant did not differ significantly to the genotypes, spacing and fertilizer levels interactions (Table 4.13a).

4.2.8 Test weight of 100 seeds.

The data on test weight of 100 seeds in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.14 and 4.14a.

Arka Komal (G_1) was recorded significantly higher test weight of 100 seeds (39.07 g) over the Burpee Stringless (G_2) (37.50 g).

Highest test weight of 100 seeds (39.64 g) was in spacing S_3 which was on par with spacing S_2 (38.17 g). The lowest (37.05g) was in spacing S_1 which was also on par with spacing S_2.

Higher test weight of 100 seeds (39.54 g) was in fertilizer level F_3 which was on par with fertilizer level F_1 (38.83 g). Significantly lowest (36.48 g) was in fertilizer level F_2.

Test weight of 100 seeds did not differ significantly due to genotypes, spacings and fertilizer levels interactions (Table 4.14 a).

4.2.9 Shelling percentage.

The data on the shelling percentage in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.14 and 4.14 a.

Table 4.14 : Test weight of 100 seeds, shelling percentage and harvest index of french bean in relation to genotypes, spacings and fertilizer levels

Treatments	Test weight of 100 seeds (g)	Shelling (%)	Harvest index
Genotypes (G)			
G_1	39.07	78.32	0.48
G_2	37.50	70.96	0.47
S. Em ±	0.48	0.13	0.004
CD (P = 0.05)	1.33	0.37	0.01
Sapcings (S)			
S_1	37.05	72.86	0.48
S_2	38.17	74.61	0.48
S_3	39.64	76.47	0.47
S. Em ±	0.59	0.16	0.005
CD (P = 0.05)	1.63	0.45	NS
Fertilizer levels (F)			
F_1	38.83	74.67	0.47
F_2	36.48	73.67	0.46
F_3	39.54	75.59	0.47
S. Em ±	0.59	0.16	0.005
CD (P = 0.05)	1.63	0.45	NS
CV. (%)	6.53	0.92	4.83

NS= Non-significant

Table 4.14a : Test Weight of 100 seeds, shelling percentage and harvest index of french bean in relation to interactions of genotypes spacings and fertilizer levels at harvest

Treatments	Test weight of 100 seeds (g)			Shelling (%)			Harvest index		
	G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)									
S_1	37.50	36.60		76.17	69.54		0.48	0.47	
S_2	38.76	37.58		78.30	70.91		0.49	0.46	
S_3	40.96	38.32		80.50	72.43		0.47	0.45	
S.Em ±		0.83			0.23			0.77	
CD (P = 0.05)		NS			0.64			NS	
Genotypes (G) x Fertilizer levels (F)									
F_1	39.57	38.09		78.50	70.83		0.48	0.47	
F_2	37.28	36.69		77.02	70.32		0.48	0.47	
F_3	40.37	38.72		79.44	71.73		0.48	0.46	
S.Em ±		0.83			0.23			0.77	
CD (P = 0.05)		NS			NS			NS	
Fertilizer levels (F) x Spacings (S)									
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	37.23	35.03	38.40	72.78	71.97	73.82	0.48	0.48	0.48
S_2	38.85	36.15	39.50	74.75	73.62	75.45	0.47	0.48	0.47
S_3	39.92	38.27	40.73	76.47	75.43	77.50	0.47	0.46	0.46
S.Em ±			1.02			0.28			0.94
CD (P = 0.05)			NS			NS			NS
Genotypes (G) x Spacings (S) x Fertilizer levels (F)									
	G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	38.37	37.07		76.10	69.47		0.47	0.48	
S_1F_2	35.40	34.67		75.13	68.80		0.48	0.48	
S_1F_3	38.73	38.07		77.27	70.37		0.48	0.47	
S_2F_1	39.40	38.30		78.57	70.93		0.48	0.47	
S_2F_2	36.43	35.87		76.97	70.27		0.48	0.47	
S_2F_3	40.43	38.57		79.37	71.53		0.49	0.46	
S_3F_1	40.93	38.90		80.33	72.10		0.48	0.46	
S_3F_2	40.00	36.53		78.97	71.90		0.48	0.46	
S_3F_3	41.93	39.53		81.70	73.90		0.48	0.45	
S.Em ±		1.44			0.40		0.47	1.33	
CD (P = 0.05)		NS			NS			NS	
CV (%)		6.53			0.92			4.84	

NS = Non-significant

Significantly highest shelling percentage (78.32) was in Arka Komal (G_1) over the Burpee Stringless (G_2) (70.96).

Significantly higher shelling percentage (76.47) was in spacing S_3. Spacing S_2 recorded significantly higher shelling percentage (74.61) over the spacing S_1 (72.86) and the lowest was in the latter.

Fertilizer level F_3 recorded significantly higher shelling percentage (75.59) followed by fertilizer level F_1 (74.67 %) and the differences among them being significant. The lowest (73.67%) was in fertilizer level F_2.

Shelling percentage due to interaction between genotypes and spacings were differed significantly. Significantly highest shelling percentage (80.50) was in interaction G_1S_3 followed G_1S_1, G_2S_3, G_2S_2 and G_2S_1 (78.30, 76.17, 72.43, 70.91 and 69.54% respectively) and the differences among being significant. The lowest was in G_2S_1.

Interactions of genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not influence significantly the shelling percentage (Table 4.14a).

4.2.10 Harvest Index

The data on harvest index in relation to genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.14 and 4.14a.

Arka Komal recorded significantly higher harvest index (0.48) over the Burpee stringless (0.47).

Harvest index did not vary significantly due to various spacings and fertilizer levels (Table 4.14).

Harvest index also did not vary significantly to genotypes, spacings and fertilizer levels interactions (Table 4.14a).

4.3 Plant tissue Analysis

4.3.1 Nitrogen accumulation in various plant parts at harvest

Nitrogen accumulation in various plant parts at harvest as influenced by genotypes, spacings and fertilizer levels and their interaction are presented in Tables 4.15 and 4.15a.

4.3.1 Nitrogen accumulation in stem at harvest

Nitrogen accumulation in stem at harvest was significantly higher in Arka Komal (G_1) (1.191%) over the Burpee Stringless (G_2) (1.171%).

Spacing S_3 showed significantly higher nitrogen accumulation in stem (1.222%) followed by spacing S_2 (1.186%) and the differences between them was significant. Significantly lower accumulation of nitrogen in Stem (1.136%) was in spacing S_1.

Significantly higher nitrogen accumulation in stem (1.207%) was in fertilizer level F_3 followed by fertilizer level F_1 (1.186%). Fertilizer level F_2 showed significantly lower accumulation of nitrogen in stem (1.151%).

Nitrogen accumulation in stem did not differ statistically with respect to genotypes, spacing and fertilizer levels interactions (Table 4.15a).

4.3.1.2 Nitrogen accumulation in leaf at harvest.

Arka Komal recorded significantly higher accumulation of nitrogen in leaf (2.690%) over the Burpee Stringless (2.623%).

Significantly higher nitrogen accumulation in leaf (2.759%) was in spacing S_3 followed by the spacing S_2 (2.638%). Spacing S_1 recorded significantly lower nitrogen accumulation in leaf (2.572%).

Fertilizer level F_3 recorded significantly higher nitrogen accumulation in leaf (2.714%) followed by the fertilizer level F_1 (2.659%). Significantly lower nitrogen accumulation in leaf (2.597%) was in fertilizer level F_2.

Genotypes x spacing, genotypes x fertilizer levels, fertilizer levels x spacing and genotypes x spacing x fertilizer levels interactions did not influence significantly the nitrogen accumulation in leaf (Table 4.15a).

4.3.1.3 Nitrogen accumulation in Pod at harvest.

Nitrogen accumulation in Pod was significantly higher (3.755%) in Arka Komal than Burpee Stringless (3.720%).

Spacing S_3 showed significantly higher nitrogen accumulation in pod (3.819%) than spacing S_2 and S_1 (3.744% and 3.649% respectively) and the differences among them being significant.

Significantly higher nitrogen accumulation in pod (3.783%) was in fertilizer level F_3 and this followed by the fertilizer level F_1 (3.741%) and the differences among them being significant. Fertilizer level F_2 recorded significantly lower nitrogen accumulation in pod (3.688%).

Nitrogen accumulation in pod did not influence significantly to all interactions of genotypes, spacings and fertilizer levels (Table 4.15a).

4.3.1.4 Nitrogen accumulation in root at harvest.

Arka Komal recorded significantly higher nitrogen accumulation in root (1.926%) than Burpee Stringless (1.875%).

Table 4.15 : Nitrogen accumulation in various plant parts of french bean at harvest in relation to genotypes, spacings and fertilizer levels

Treatments	Nitrogen accuIumulation (%) in various plant parts			
	Stem	Leaf	Pod	Root
Genotypes (G)				
G_1	1.191	2.690	3.755	1.926
G_2	1.171	2.623	3.720	1.875
S. Em ±	0.006	0.010	0.009	0.007
CD (P = 0.05)	0.017	0.027	0.025	0.020
Sapcings (S)				
S_1	1.136	2.572	3.649	1.813
S_2	1.186	2.638	3.744	1.893
S_3	1.222	2.759	3.819	1.995
S. Em ±	0.008	0.012	0.011	0.009
CD (P = 0.05)	0.021	0.033	0.030	0.025
Fertilizer levels (F)				
F_1	1.186	2.659	3.741	1.897
F_2	1.151	2.597	3.688	1.842
F_3	1.207	2.714	3.783	1.962
S. Em ±	0.008	0.012	0.011	0.009
CD (P = 0.05)	0.021	0.033	0.033	0.025
CV. (%)	2.780	1.920	1.240	2.020

Table 4.15a : Nitrogen accumulation in various plant parts of french bean in relation to interactions of genotypes spacings and fertilizer levels at harvest

Treatments	Stem			Leaf			Pod			Root		
	Nitrogen accumulation (%) in various plant parts											
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	1.147	1.126		2.591	2.553		3.672	3.626		1.838	1.789	
S_2	1.197	1.176		2.671	2.606		3.758	3.730		1.896	1.890	
S_3	1.232	1.212		2.809	2.710		3.834	3.803		2.043	1.947	
S.Em ±		0.011			0.017			0.015			0.013	
CD (P = 0.05)		NS			NS			NS			0.035	
Genotypes (G) x Fertilizer levels (F)												
F_1	1.198	1.174		2.698	2.621		3.759	3.722		1.918	1.877	
F_2	1.160	1.142		2.619	2.574		3.708	3.668		1.848	1.836	
F_3	1.218	1.197		2.754	2.673		3.798	3.769		2.011	1.913	
S.Em ±		0.011			0.017			0.015			0.013	
CD (P = 0.05)		NS			NS			NS			0.035	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	1.148	1.092	1.168	2.573	2.533	2.610	3.648	3.590	3.708	1.810	1.753	1.877
S_2	1.188	1.162	1.208	2.645	2.555	2.715	3.750	3.697	3.785	1.908	1.843	1.927
S_3	1.221	1.220	1.245	2.760	2.702	2.817	3.823	3.777	3.857	1.973	1.928	2.083
S.Em ±		0.013			0.021			0.019			0.016	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	1.163	1.133		2.597	2.550		3.677	3.620		1.823	1.797	
S_1F_2	1.097	1.087		2.543	2.523		3.620	3.560		1.783	1.723	
S_1F_3	1.180	1.157		2.633	2.587		3.720	3.697		1.907	1.847	
S_2F_1	1.200	1.177		2.680	2.610		3.763	3.737		1.920	1.897	
S_2F_2	1.173	1.150		2.567	2.543		7.707	3.687		1.827	1.860	
S_2F_3	1.217	1.200		2.767	2.663		7.803	3.767		1.940	1.913	
S_3F_1	1.230	1.213		2.817	2.703		3.837	3.810		2.010	1.937	
S_3F_2	1.210	1.190		2.746	2.656		3.797	3.757		1.933	1.923	
S_3F_3	1.257	1.233		2.863	2.770		3.870	3.843		2.187	1.980	
S.Em ±		0.030			0.050			0.050			0.040	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		0.780			1.920			1.240			2.020	

NS = Non-significant

Spacing S_3 recorded significantly higher nitrogen accumulation in root (1.995%) followed by the spacing S_2 (1.893%). Significantly lower nitrogen accumulation in root (1.813%) was in spacing S_1.

Significantly higher nitrogen accumulation in root (1.962%) was in fertilizer level F_3 followed by the fertilizer level F_1 (1.897%) and the differences between them being significant. Fertilizer level F_2 recorded significantly lower accumulation of nitrogen in root (1.842%).

Significant variation in accumulation of nitrogen in root was recorded to interactions of genotypes x spacings and genotypes x fertilizer levels.

Significantly higher accumulation of nitrogen in root (2.043%) was in interaction of G_1 S_3 compared to other interactions, followed by interactions G_2 S_3 and G_1 S_2 (1.947 and 1.896% respectively) and the differences among them being significant. The interactions G_1 S_2 and G_2 S_2 were at par. Significantly lowest nitrogen accumulation in root (1.789%) was in interaction G_2 S_1.

Significantly highest N accumulation in root (2.011%) was in G_2 F_3 combination followed by combination of G_1 F_1 and G_2 F_3 were at par and also G_1 F_2 and G_2 F_2. The lowest accumulation of N in root (1.836%) was in G_2 F_2 combination.

4.3.2 Phosphorus accumulation in various plant parts at harvest.

Phosphorus accumulation in stem, leaf, pod and root at harvest as influenced by genotypes, spacings and fertilizer levels and their interactions are presented in Tables 4.16 and 4.16a.

4.3.2.1 Phosphorus accumulation in stem at harvest.

Arka Komal recorded significantly higher accumulation of phosphorus in stem (0.075%) than Burpee Stringless (0.072%).

Phosphorus accumulation in stem (0.079%) was significantly higher in spacing S_3 followed by spacing S_2 (0.073%) and the differences among them being significant. Significantly the lowest phosphorus (0.069%) content was in spacing S_1.

Phosphorus accumulation in stem was significantly higher in fertilizer level F_3 (0.076%) followed by fertilizer level F_1 (0.074%). Fertilizer level F_2 recorded significantly lower phosphorus content in stem (0.071%).

Phosphorus accumulation in stem did not differ significantly to all interactions of genotypes, spacings and fertilizer levels (Table 4.16a).

4.3.2.2 Phosphorus accumulation in leaf at harvest.

Phosphorus accumulation in leaf at harvest did not vary significantly between Arka Komal and Burpee Stringless (Table 4.16a).

At harvest spacing S_3 recorded significantly higher phosphorus accumulation in leaf (0.045%) followed by spacing S_2 (0.042%) and the differences among them being significant. Significantly lower phosphorus accumulation in leaf (0.039%) was in spacing S_1.

Phosphorus accumulation at harvest in leaf (0.044%) was found to be significantly higher in fertilizer level F_3. This was followed by fertilizer level F_1 (0.041%) which was in par with fertilizer level F_2 (0.040%).

Phosphorus accumulation at harvest in leaf did not vary significantly to all interactions of genotypes, spacings and fertilizer levels (Table 4.16a).

4.3.2.3 Phosphorus accumulation in pod at harvest.

Phosphorus accumulation at harvest in pod was significantly higher in Arka Komal (0.342%) than Burpee Stringless (0.330%).

Table 4.16 : Phosphorus accumulation in various plant parts of french bean at harvest in relation to genotypes, spacings and fertilizer levels

	Phosphorus accumulation (%) in various plant parts			
Treatments	Stem	Leaf	Pod	Root
Genotypes (G)				
G_1	0.075	0.043	0.342	0.048
G_2	0.072	0.041	0.330	0.042
S. Em ±	0.001	0.001	0.003	0.001
CD (P = 0.05)	0.002	NS	0.009	0.002
Sapcings (S)				
S_1	0.069	0.039	0.307	0.041
S_2	0.073	0.042	0.332	0.044
S_3	0.079	0.045	0.369	0.050
S. Em ±	0.001	0.001	0.004	0.001
CD (P = 0.05)	0.002	0.002	0.011	0.002
Fertilizer levels (F)				
F_1	0.074	0.041	0.340	0.045
F_2	0.075	0.040	0.315	0.043
F_3	0.076	0.044	0.353	0.047
S. Em ±	0.001	0.001	0.004	0.001
CD (P = 0.05)	0.002	0.002	0.011	0.002
CV. (%)	4.340	4.340	4.840	3.250

NS = Non-significant

Table 4.16a : Phosphorus accumulation in various plant parts of french bean in relation to interactions of genotypes spacings and fertilizer levels at harvest

Treatments	Phosphorus accumulation (%) in various plant parts											
		Stem			Leaf			Pod			Root	
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	0.070	0.068		0.041	0.039		0.316	0.299		0.044	0.038	
S_2	0.074	0.072		0.043	0.041		0.337	0.328		0.046	0.042	
S_3	0.081	0.076		0.046	0.044		0.374	0.364		0.053	0.047	
S.Em ±		0.001			0.010			0.005			0.000	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)												
F_1	0.075	0.072		0.042	0.041		0.035	0.333		0.048	0.042	
F_2	0.072	0.069		0.041	0.040		0.320	0.310		0.045	0.041	
F_3	0.078	0.075		0.045	0.043		0.359	0.348		0.050	0.045	
S.Em ±		0.001			0.001			0.005			0.001	
CD (P = 0.05)		NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_L	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.070	0.067	0.072	0.038	0.038	0.042	0.308	0.288	0.325	0.041	0.039	0.043
S_2	0.073	0.071	0.075	0.041	0.400	0.044	0.340	0.303	0.353	0.044	0.042	0.046
S_3	0.078	0.075	0.083	0.045	0.043	0.047	0.373	0.353	0.382	0.049	0.048	0.052
S.Em ±		0.001			0.001			0.007			0.001	
CD (P = 0.05)		NS			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	0.070	0.069		0.039	0.038		0.320	0.297		0.045	0.038	
S_1F_2	0.068	0.065		0.038	0.037		0.293	0.283		0.042	0.036	
S_1F_3	0.072	0.071		0.042	0.041		0.333	0.317		0.046	0.040	
S_2F_1	0.073	0.072		0.043	0.039		0.347	0.333		0.047	0.042	
S_2F_2	0.069	0.070		0.041	0.040		0.307	0.300		0.043	0.041	
S_2F_3	0.077	0.073		0.044	0.043		0.357	0.350		0.049	0.044	
S_3F_1	0.081	0.075		0.046	0.045		0.377	0.370		0.052	0.046	
S_3F_2	0.079	0.072		0.043	0.042		0.360	0.347		0.051	0.045	
S_3F_3	0.083	0.081		0.048	0.046		0.387	0.378		0.054	0.051	
S.Em ±		0.001			0.001			0.002			0.001	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		4.340			7.280			4.840			3.250	

NS = Non-significant

Phosphorus accumulation at harvest in pod was significantly, higher in spacing S_3 (0.369%) followed by spacing S_2 (0.332%). Significantly lowest Phosphorus accumulation at harvest in pod (0.307%) was in spacing S_1.

Fertilizer level F_3 at harvest recorded significantly higher phosphorus accumulation in pod (0.353%) followed by fertilizer level F_1 (0.340%). Fertilizer level F_2 showed significantly lower phosphorus accumulation in pod (0.315%).

Phosphorus accumulation in pod was not affected significantly by interaction of genotypes, spacings and fertilizer levels (Table 4.16a).

4.3.2.4 Phosphorus accumulation in root at harvest

Arka Komal at harvest recorded significantly higher phosphorus accumulation in root (0.048%) than Burpee Stringless (0.042%).

Phosphorus accumulation at harvest in root was significantly higher in spacing S_3 (0.050%) followed by spacing S_2 (0.044%) and the differences among them being significant. Significantly lowest phosphorus accumulation in root (0.041%) was in spacing S_1.

At harvest significantly higher phosphorus accumulation in root was in fertilizer level F_3 (0.047%) followed by the fertilizer level F_1 (0.045%). Fertilizer level F_2 recorded significantly lowest phosphorus accumulation in root (0.043%).

Interaction effects of genotypes, spacings and fertilizer levels had no significant influence on the phosphorus accumulation in root at harvest (Table 4.16a).

4.3.3 Potassium accumulation in various plant parts at harvest.

Potassium accumulation in stem, leaf, pod and root at harvest as influenced by genotypes, spacings and fertilizer levels are presented in Tables 4.17 and 4.17a.

4.3.3.1 Potassium accumulation in stem at harvest

Potassium accumulation at harvest in stem was significantly higher in Arka Komal (2.573%) than Burpee Stringless (2.437%).

Spacing S_3 recorded significantly higher potassium accumulation in stem (2.643%) at harvest followed by spacing S_2 (2.527%). Significantly lowest potassium accumulation in stem (2.345%) was in spacing S_1.

Fertilizer level F_3 recorded significantly higher potassium accumulation in stem (2.589%) at harvest followed by fertilizer level F_1 (2.519%) and the differences among them being significant. Significantly lowest potassium accumulation in stem at harvest (2.407%) was in fertilizer level F_2.

Genotypes x spacings and fertilizer x spacings interactions had significant influence on the potassium accumulation in stem. While other interactions effect of genotypes x fertilizer and genotypes x spacings x fertilizer levels were non-significant.

Significantly higher potassium content in stem was in combination of G_1S_3 (2.753%). Combination of G_1S_2 (2.586%) was on par with G_2S_3 (2.532%). Potassium accumulation in stem was significantly lower (2.309%) in G_2S_1 combination followed by G_1S_1 combination (2.381%) which was on par with G_2S_2 combination (2.469%).

Interaction combination of F_3S_3 recorded significantly higher potassium accumulation in stem (2.722%). Combination of F_1S_3 (2.633%) and F_2S_3 (2.573%) were at par. Potassium accumulation in stem was significantly lowest in the combination of F_2S_1 (2.157%).

4.3.3.2 Potassium accumulation in leaf at harvest.

Potassium accumulation in leaf did not differ significantly between Arka Komal and Burpee Stringless (Table 4.17).

Potassium accumulation in leaf was significantly higher in spacing S_3 (3.368%) followed by spacing S_2 (3.147%) and the differences among them being significant. Significantly lowest potassium accumulation in leaf (2.853%) was in spacing S_1.

Fertilizer level F_3 recorded significantly higher potassium accumulation in leaf (3.268%) which was on par with F_1 (3.144%). Significantly lower potassium accumulation in leaf (2.956%) was in fertilizer level F_2.

Potassium accumulation in leaf did not influence significantly to all interaction effects of genotypes, spacings and fertilizer levels (Table 4.17a).

4.3.3.3 Potassium accumulation in pod at harvest.

Potassium accumulation in pod did not differ significantly between Arka Komal and Burpee Stringless (Table 4.17).

Spacing S_3 recorded significantly higher potassium accumulation in pod (3.903%) followed by spacing S_2 (3.562%) and the differences between them being significant. Spacing S_1 recorded significantly lowest (3.434%) potassium accumulation in pod.

Table 4.17 : Patassium accumulation in various plant parts of french bean at harvest in relation to genotypes, spacings and fertilizer levels

	Patassium accuℓumulation (%) in various plant parts			
Treatments	Stem	Leaf	Pod	Root
Genotypes (G)				
G_1	2.573	3.158	3.654	1.273
G_2	2.437	3.087	3.613	1.255
S. Em ±	0.015	0.040	0.028	0.008
CD (P = 0.05)	0.042	NS	NS	0.022
Sapcings (S)				
S_1	2.345	2.853	3.434	1.205
S_2	2.527	3.147	3.562	1.265
S_3	2.643	3.368	3.903	1.322
S. Em ±	0.019	0.050	0.035	0.010
CD (P = 0.05)	0.051	0.137	0.097	0.027
Fertilizer levels (F)				
F_1	2.519	3.144	3.665	1.268
F_2	2.407	2.956	3.511	1.218
F_3	2.589	3.268	3.724	1.306
S. Em ±	0.019	0.500	0.035	0.010
CD (P = 0.05)	0.051	0.137	0.097	0.027
CV. (%)	3.140	6.730	4.070	3.290

NS = Nonsignificant

Table 4.17a : Potassium accumulation in various plant parts of french bean in relation to interactions of genotypes spacings and fertilizer levels at harvest

Treatments	Potassium accumulation (%) in various plant parts											
	Stem			Leaf			Pod			Root		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)												
S_1	2.381	2.309		2.890	2.816		3.458	3.411		1.216	1.194	
S_2	2.586	2.469		3.182	3.112		3.593	3.530		1.274	1.256	
S_3	2.753	2.532		3.402	3.334		3.910	3.897		1.330	1.314	
S.Em ±		0.026			0.070			0.028			0.014	
CD (P = 0.05)		0.073			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)												
F_1	2.570	2.468		3.178	3.111		3.682	3.647		1.278	1.259	
F_2	2.470	2.344		2.989	2.989		3.531	3.490		1.228	1.208	
F_3	2.680	2.498		3.308	3.228		3.748	3.700		1.314	1.298	
S.Em ±		0.026			0.070			0.035			0.014	
CD (P = 0.05)		NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)												
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	2.408	2.157	2.470	2.835	3.233	3.365	3.450	3.617	3.928	1.197	1.170	1.248
S_2	2.515	2.492	2.572	2.727	2.940	3.202	3.328	3.413	3.790	1.263	1.232	1.300
S_3	2.633	2.573	2.722	2.987	2.268	3.538	3.538	3.655	3.992	1.345	1.252	1.370
S.Em ±		0.032			0.086			0.035			0.017	
CD (P = 0.05)		0.089			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)												
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	2.420	2.397		2.860	2.810		3.447	3.433		1.213	1.180	
S_1F_2	2.187	2.127		2.767	2.687		3.363	3.293		1.180	1.160	
S_1F_3	2.537	2.403		3.043	2.950		3.543	3.507		1.253	1.243	
S_2F_1	2.567	2.463		3.277	3.190		3.647	3.587		1.270	1.257	
S_2F_2	2.550	2.433		2.960	2.920		3.427	3.400		1.243	1.220	
S_2F_3	2.640	2.510		3.310	3.227		3.707	3.603		1.310	1.290	
S_3F_1	2.723	2.543		3.397	3.333		3.933	3.923		1.350	1.340	
S_3F_2	2.673	2.473		3.240	3.163		3.803	3.778.		1.260	1.243	
S_3F_3	2.863	2.580		3.570	3.507		3.993	3.990		1.380	1.360	
S.Em ±		0.080			0.210			0.150			0.040	
CD (P = 0.05)		NS			NS			NS			NS	
CV (%)		3.140			6.730			4.070			3.290	

NS = Non-significant

Significantly higher potassium accumulation in pod was in fertilizer level F_3 (3.724%) which was on par with fertilizer level F_1 (3.665%). Potassium accumulation in pod was significantly lowest (3.511%) in fertilizer level F_2.

Interaction effects of genotypes, spacings and fertilizer levels did not show significant difference in potassium accumulation in pod.

4.3.3.4 Potassium accumulation in root at harvest.

Arka Komal recorded significantly higher potassium accumulation in root (1.273%) than Burpee Stringless (1.255%).

Significantly higher potassium accumulation in root (1.322%) was recorded in spacing S_3 followed by spacing S_2 (1.265%) and the differences among them being significant. Spacing S_1 recorded significantly lowest potassium accumulation in root (1.205%).

Fertilizer level F_3 recorded significantly higher potassium accumulation in root (1.306%) followed by fertilizer level F_1 (1.268%) and the differences among them being significant. Significantly lowest potassium accumulation in root (1.218%) was in fertilizer level F_2.

Potassium accumulation in root did not differ significantly to interactions effects of genotypes, spacings and fertilizer levels (Table 4.17a).

4.4 Uptake of Nutrients

4.4.1 Nitrogen uptake by various plant parts

Nitrogen uptake by stem, leaf, pod, root and total at harvest as influenced by genotypes, spacings and fertilizer levels are presented in Tables 4.18 and 4.18a.

4.4.1.1 Nitrogen uptake by Stem

Arka Komal at harvest showed significantly higher uptake of nitrogen by stem (10.36 kg /ha) over the Burpee Stringless (9.13 kg /ha).

Significantly higher uptake of nitrogen (11.49 kg /ha) by stem was in spacing S_1 followed by spacing S_2 (9.48 kg /ha) and differences between them being significant. Spacing S_3 recorded the lowest uptake of nitrogen (8.26 kg /ha) by stem.

Uptake of nitrogen by stem (10.46 kg /ha) was significantly higher in fertilizer level F_3. This was followed by the fertilizer level F_1 (9.77 kg /ha). Significantly lower uptake of nitrogen by stem (9.00 kg /ha) was in fertilizer level F_2.

Nitrogen uptake by stem did not influence significantly to all the interaction effects of genotypes, spacings and fertilizer levels (Table 4.18a).

4.4.1.2 Nitrogen uptake by leaf.

Nitrogen uptake by leaf was significantly higher in Arka Komal (20.82 kg /ha) over the Burpee Stringless (18.66 kg /ha).

Nitrogen uptake by leaf (22.12 kg /ha) was significantly higher in spacing S_1. The lowest uptake of nitrogen by leaf (18.37 kg /ha) was in spacing S_3 which was on par with spacing S_2 (18.73 kg /ha).

Fertilizer level F_3 showed significantly higher uptake of nitrogen by leaf (21.23 kg /ha). This was followed by fertilizer level F_1 (19.84 kg /ha). Significantly lowest uptake of nitrogen by leaf (18.15 kg /ha) was in fertilizer level F_2.

Table 4.18 : Nitrogen uptake by various plant parts of french bean at harvest as influenced by genotypes, spacings and fertilizer levels

	Nitrogen uptake (kg/ha) by various plant parts				
Treatments	Stem	Leaf	Pod	Root	Total
Genotypes (G)					
G_1	10.36	20.82	96.75	5.97	133.90
G_2	9.13	18.66	85.41	5.55	118.75
S. Em ±	0.13	0.34	1.23	0.08	1.55
CD (P = 0.05)	0.37	0.95	3.50	0.21	4.31
Sapcings (S)					
S_1	11.49	22.12	110.01	6.61	150.23
S_2	9.48	18.73	89.64	5.80	123.65
S_3	8.26	18.37	73.58	4.88	105.09
S. Em ±	0.16	0.42	1.55	0.09	1.90
CD (P = 0.05)	0.45	1.16	4.29	0.26	5.28
Fertilizer levels (F)					
F_1	9.77	19.84	91.82	5.74	127.17
F_2	9.00	18.15	86.43	5.30	118.88
F_3	10.46	21.23	94.99	6.24	132.92
S. Em ±	0.16	0.42	1.55	0.09	1.90
CD (P = 0.05)	0.45	1.16	4.29	0.26	5.28
CV. (%)	7.11	8.98	7.21	6.95	6.33

Table 4.18a : Nitrogen uptake by various plant parts of french bean at harvest in relation to interactions of genotypes spacings and fertilizer levels

Treatments	Stem			Leaf			Pod			Root			Total		
	Nitrogen uptake (kg ha^{-1}) by various plant parts														
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)															
S_1	12.30	10.69		22.99	21.24		115.16	104.86		6.95	6.25		157.38	143.04	
S_2	10.12	8.84		19.17	18.30		95.50	83.78		5.86	5.74		134.01	116.65	
S_3	8.66	7.87		20.31	16.43		79.59	67.58		5.09	4.66		114.18	99.10	
S.Em ±		0.23			0.59			2.19			0.13			2.69	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)															
F_1	10.47	9.07		20.98	18.71		97.98	85.66		5.95	5.52		139.07	121.51	
F_2	9.51	8.50		19.04	17.26		90.48	82.38		5.45	5.14		124.47	113.27	
F_3	11.09	9.83		22.44	20.01		101.79	88.19		6.49	5.98		142.04	124.01	
S.Em ±		0.23			0.59			2.19			0.13			2.69	
CD (P = 0.05)		NS			1.64			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)															
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	11.57	10.55	12.35	22.51	20.18	23.66	109.80	104.83	115.40	6.50	5.99	7.31	150.37	141.54	158.74
S_2	9.46	9.01	9.97	19.10	17.42	19.69	90.44	85.40	93.08	5.90	5.37	6.12	129.61	117.59	129.19
S_3	8.29	7.45	9.05	17.92	15.85	20.33	75.22	69.05	76.48	4.82	3.53	5.28	110.89	97.89	111.15
S.Em ±		0.28			0.72			2.68			0.16			3.29	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)															
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	12.46	10.67		23.49	21.53		114.69	104.92		6.89	6.10		157.52	143.21	
S_1F_2	11.12	9.99		20.92	19.44		108.48	101.19		6.27	5.70		146.77	136.52	
S_1F_3	13.31	11.40		24.56	22.77		122.32	108.49		7.68	6.95		167.87	149.61	
S_2F_1	10.16	8.75		19.50	18.70		96.73	84.14		5.99	5.81		141.82	117.41	
S_2F_2	9.70	8.31		17.55	17.28		88.88	81.91		5.40	5.34		121.55	112.84	
S_2F_3	10.48	9.46		20.46	18.92		100.88	85.27		6.18	6.06		138.66	119.71	
S_3F_1	8.79	7.78		19.96	15.89		82.52	67.91		4.97	4.67		117.86	103.92	
S_3F_2	7.71	7.19		18.65	15.06		74.07	64.03		4.67	4.39		105.11	90.66	
S_3F_3	9.48	8.63		22.31	18.35		82.17	70.80		5.63	4.93		119.59	102.71	
S.Em ±		0.69			1.77			6.57			4.00			8.06	
CD (P = 0.05)		NS			NS			NS			NS			NS	
CV (%)		7.11			8.98			7.21			6.95			6.33	

NS = Non-significant

Interaction effect of genotypes and fertilizer levels showed significant differences in nitrogen uptake by leaf. It was significantly higher (22.44 kg /ha) in G_1F_3 combination followed by combinations of G_1F_1 (20.98 kg /ha) and G_2F_3 (20.01 kg /ha) which were at par. Nitrogen uptake by leaves was significantly lower in combination of G_2 F_3 (17.26 kg /ha). Interaction effects of G_2 F_1 (18.71 kg /ha) and G_1 F_2 (19.04 kg /ha) were at par.

Genotypes x spacings, fertilizers levels x spacings and genotypes x spacings x fertilizer levels interactions had no significant effect in the uptake of nitrogen by leaf.

4.4.1.3 Nitrogen uptake by pod.

Nitrogen uptake by pod was significantly higher in Arka Komal G_1 (96.75 kg /ha) than Burpee Stringless G_2 (85.41 kg /ha).

Spacing S_1 showed significantly higher uptake of nitrogen by pod (110.01 kg /ha) followed by spacing S_2 (89.64 kg /ha) and the differences between them being significant. Significantly lower uptake by nitrogen by pod was in spacing S_3 (73.58 kg /ha).

Nitrogen uptake by pod (94.99 kg /ha) was significantly higher in fertilizer level F_3. This was followed by fertilizer level F_1 (91.82 kg /ha). Significantly lower uptake of nitrogen by pod (86.43 kg /ha) was in fertilizer level F_2.

Nitrogen uptake by pod at harvest did not differ significantly to interaction effects of genotypes, spacings and fertilizer levels (Table 4.18a).

4.4.1.4 Nitrogen uptake by root

Significantly higher uptake of nitrogen by root at harvest was in Arka Komal (5.97 kg /ha) than Burpee Stringless (5.55 kg /ha).

Nitrogen uptake by root at harvest was significantly higher in spacing S_1 (6.61 kg /ha) followed by spacing S_2 (5.80 kg /ha) and the differences among them being significant. Significantly lower uptake of nitrogen by root at harvest (4.88 kg /ha) was in spacing S_3.

At harvest fertilizer level F_3 showed significantly higher uptake of nitrogen by root (6.24 kg /ha) followed by fertilizer level F_1 (5.74 kg /ha). Nitrogen uptake by root at harvest was significantly lower in fertilizer level F_2 (5.30 kg /ha).

Interaction effects of genotypes, spacings and fertilizer levels did not influence significantly the nitrogen uptake by root at harvest (Table 4.18a).

4.4.1.5 Total nitrogen uptake at harvest.

Total nitrogen uptake was significantly higher in Arka Komal G_1 (133.90 kg /ha) than Burpee Stringless G_2 (118.75 kg /ha).

Significantly higher total nitrogen uptake was in spacing S_1 (150.23 kg /ha) followed by spacing S_2 (123.65 kg /ha). Spacing S_3 recorded significantly lowest total uptake of nitrogen (105.09 kg /ha).

Total nitrogen uptake was significantly higher in fertilizer level F_3 (132.92 kg /ha) followed by fertilizer level F_1 (127.17 kg /ha). Significantly lower uptake of nitrogen (118.88 kg /ha) was in fertilizer level F_2.

Total nitrogen uptake did not differ significantly to the interaction effects of genotypes, spacings and fertilizer levels (Table 4.18a).

4.5.1 Phosphorus uptake by various plant parts at harvest.

Phosphorus uptake by stem, leaf, pod, root and total at harvest as influenced by genotypes, spacings and fertilizer levels are presented in Tables 4.19 and 4.19a.

4.5.1.1 Phosphorus uptake by Stem at harvest.

Arka Komal recorded significantly higher uptake of phosphorus by stem (0.66 kg /ha) over the Burpee Stringless (0.56 kg /ha).

Spacing S_1 showed significantly higher uptake of phosphorus by stem (0.70 kg /ha). This was followed by spacing S_2 (0.59 kg /ha) significantly lower uptake of phosphorus by stem was in spacing S_3 (0.53 kg /ha).

Phosphorus uptake by stem was significantly higher in fertilizer level F_3 (0.67 kg /ha) followed by fertilizer level F_1 (0.61 kg /ha) and the difference between them being significant. Significantly lower uptake of phosphorus by stem was in fertilizer level F_2 (0.55 kg /ha).

Interactions among genotypes, spacings and fertilizer levels were did not differ significantly in uptake of phosphorus by stem.

4.5.1.2 Phosphorus uptake by leaf at harvest

Phosphorus uptake by leaf was significantly higher in Arka Komal (0.33 kg /ha) than Burpee Stringless (0.30 kg /ha).

Phosphorus uptake by leaf was significantly higher in spacing S_1 (0.34 kg /ha) followed by spacing S_2 (0.31 kg /ha) and the difference among them being significant. Significantly lowest uptake of phosphorus by leaf (0.30 kg /ha) was in spacing S_3.

Fertilizer level F_3 showed significantly higher uptake of phosphorus by leaf (0.34 kg /ha). This was followed by fertilizer level F_1 (0.32 kg /ha).

Significantly lowest uptake of phosphorus by leaf (0.28 kg /ha) was in fertilizer level F_2.

Interaction effects of genotypes and spacings showed significant difference in uptake of phosphorus by leaf. Highest uptake of phosphorus (0.36 kg /ha) was in interaction combination of G_1S_1 followed by G_1S_3 (0.33 kg /ha) which were at par. Interaction effect of G_2S_1, G_1S_2 and G_2S_3 (0.32, 0.31 and 0.31 kg /ha respectively) were also at par. Significantly lowest uptake of phosphorus by leaf was in G_2S_3 interaction effect (0.27 kg /ha).

4.5.1.3 Phosphorus uptake by pod at harvest.

Phosphorus uptake by pod in Arka Komal was significantly higher (8.76 kg /ha) than Burpee Stringless (7.50 kg /ha).

Spacing S_1 showed significantly higher uptake of phosphorus by pod (9.29 kg /ha) followed by spacing S_2 (8.00 kg /ha). Significantly lowest uptake of phosphorus by pod was in spacing S_3 (7.11 kg /ha).

Phosphorus uptake by pod was significantly higher in fertilizer level F_3 (8.79 kg /ha). This was followed by fertilizer level F_1 (8.27 kg/ha). Significantly lower phosphorus uptake by pods was in fertilizer level F_2 (7.33 kg /ha).

Interaction effects of genotypes, spacings and fertilizer levels did not effect significantly the uptake of phosphorus by pod (Table 4.19a).

4.5.1.4 Phosphorus uptake by root at harvest.

Arka Komal showed significantly higher uptake of phosphorus by root (0.15 kg /ha) over the Burpee Stringless (0.13 kg /ha).

Table 4.19 : Phosphorus uptake by various plant parts of french bean at harvest as influenced by genotypes, spacings and fertilizer levels

	Phosphorus uptake (kg /ha) by various plant parts				
Treatments	Stem	Leaf	Pod	Root	Total
Genotypes (G)					
G_1	0.66	0.33	8.76	0.15	9.89
G_2	0.56	0.30	7.50	0.13	8.49
S. Em ±	0.009	0.007	0.147	0.002	0.148
CD (P = 0.05)	0.026	0.021	0.408	0.01	0.412
Sapcings (S)					
S_1	0.70	0.34	9.28	0.15	10.47
S_2	0.59	0.31	8.00	0.14	9.03
S_3	0.53	0.30	7.11	0.12	8.06
S. Em ±	0.01	0.01	0.18	0.002	0.18
CD (P = 0.05)	0.03	0.03	0.50	0.01	0.50
Fertilizer levels (F)					
F_1	0.61	0.32	8.27	0.14	9.33
F_2	0.55	0.28	7.33	0.12	8.29
F_3	0.67	0.34	8.79	0.15	9.95
S. Em ±	0.01	0.01	0.18	0.002	0.18
CD (P = 0.05)	0.03	0.03	0.50	0.01	0.50
CV. (%)	8.02	12.28	9.41	5.75	8.39

Table 4.19a : **Phosphorus uptake various by plant parts of french bean at harvest in relation to *interactions* of genotypes spacings and fertilizer levels**

Treatments	Phosphorus uptake (kg ha^{-1}) by various plant parts														
	Stem			Leaf			Pod			Root			Total		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)															
S_1	0.76	0.65		0.36	0.32		9.91	8.65		0.17	0.13		11.19	9.76	
S_2	0.64	0.54		0.31	0.31		8.63	7.37		0.14	0.13		9.72	8.34	
S_3	0.57	0.50		0.33	0.27		7.74	6.48		0.13	0.11		8.77	7.32	
S.Em ±		0.02			0.01			0.26			0.003			0.26	
CD (P = 0.05)		NS			0.04			NS			0.01			NS	
Genotypes (G) x Fertilizer levels (F)															
F_1	0.66	0.55		0.33	0.31		8.98	7.57		0.15	0.12		10.11	8.55	
F_2	0.59	0.51		0.30	0.27		7.77	6.89		0.13	0.11		8.96	7.78	
F_3	0.72	0.61		0.36	0.33		9.54	8.04		0.16	0.14		10.78	9.09	
S.Em ±		0.02			0.01			0.26			0.003			0.26	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)															
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.71	0.65	0.76	0.34	0.30	0.38	9.31	8.43	10.12	0.15	0.13	0.17	10.50	9.51	11.42
S_2	0.58	0.54	0.64	0.33	0.28	0.32	8.20	7.09	8.71	0.14	0.12	0.15	9.25	8.03	9.81
S_3	0.53	0.47	0.60	0.29	0.27	0.34	7.31	6.47	7.55	0.12	0.12	0.13	8.26	7.32	8.57
S.Em ±		0.02			0.02			0.31			0.003			0.32	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)															
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	0.76	0.65		0.36	0.32		9.98	8.63		0.17	0.13		11.27	9.73	
S_1F_2	0.69	0.60		0.32	0.29		8.78	8.07		0.15	0.12		9.94	9.08	
S_1F_3	0.81	0.70		0.39	0.36		10.97	9.26		0.19	0.15		12.36	10.48	
S_2F_1	0.64	0.53		0.31	0.34		8.91	7.49		0.15	0.13		10.01	8.48	
S_2F_2	0.58	0.51		0.28	0.27		7.49	6.68		0.13	0.12		8.48	7.58	
S_2F_3	0.71	0.57		0.33	0.31		9.48	7.94		0.16	0.14		10.67	8.96	
S_3F_1	0.58	0.48		0.32	0.26		8.03	6.59		0.13	0.11		9.07	7.44	
S_3F_2	0.51	0.43		0.30	0.24		7.03	5.91		0.13	0.10		7.95	6.68	
S_3F_3	0.63	0.57		0.37	0.30		8.16	6.93		0.14	0.13		9.30	7.83	
S.Em ±		0.05			0.04			0.77			0.01			2.87	
CD (P = 0.05)		NS			NS			NS			NS			NS	
CV (%)		8.02			12.28			9.41			5.75			8.39	

NS = Non-significant

Phosphorus uptake by root was significantly highest in spacing S_1 (0.15 kg /ha) followed by spacing S_2 (0.14 kg /ha) and the differences between them being significant. Significantly lower uptake of phosphorus was in spacing S_3 (0.12 kg /ha).

Fertilizer level F_3 showed significantly higher uptake of phosphorus by root (0.15 kg /ha) followed by fertilizer level F_1 (0.14 kg /ha). Significantly lowest uptake of phosphorus by root was in fertilizer level F_2 (0.12 kg /ha).

Interactions effects of genotypes and spacings differed significantly in uptake of phosphorus by root. It was significantly higher in G_1 S_1 combination (0.17 kg /ha). All other combinations of genotypes and spacings have differed significantly. Phosphorus uptake by root was significantly lowest in G_2S_3 combination (0.11 kg /ha).

Genotypes x fertilizer levels, fertilizer levels x spacings and genotypes x spacings x fertilizer levels did not influence significantly in uptake of phosphorus by root (Table 4.19a).

4.5.1.5 Total Phosphorus uptake at harvest.

Significantly higher total phosphorus uptake was in Arka Komal (G_1) (9.89 kg /ha) over the Burpee Stringless (G_2) (8.49 kg /ha).

Total phosphorus uptake was significantly higher in spacing S_1 (10.48 kg/ha) followed by spacing S_2 (9.03 kg/ha) and the differences between them being significant. Significantly lowest total phosphorus uptake was in spacing S_3 (8.06 kg /ha).

Fertilizer level F_3 recorded significantly higher total phosphorus uptake (9.95 kg /ha) followed by fertilizer level F_1 (9.33 kg /ha). Significantly lowest total phosphorus uptake (8.29 kg /ha) was in fertilizer level F_2.

Total phosphorus uptake did not differ significantly to the interaction effects of genotypes, spacing and fertilizer levels (Table 4.19a).

4.6.1 Potassium uptake by various plant parts at harvest.

Potassium uptake by stem, leaf, pod, root and total at harvest as influenced by genotypes, spacings and fertilizer levels are presented in Tables 4.20 and 4.20a.

4.6.1.1 Potassium uptake by stem at harvest.

Arka Komal showed significantly higher uptake of potassium by stem (22.53 kg /ha) than Burpee Stringless (18.98 kg /ha).

Potassium uptake by stem was significantly higher in spacing S_1 (23.78 kg /ha) followed by spacing S_2 (20.63 kg /ha) and the differences between them being significant. Significantly lower uptake of potassium by stem was in spacing S_2 (17.90 kg /ha).

Fertilizer level F_3 showed significantly higher potassium uptake by stem (22.70 kg /ha). This was followed by fertilizer level F_1 (20.84 kg /ha). Significantly lowest potassium uptake by stem was in fertilizer level F_2 (18.72 kg /ha).

Potassium uptake by stem did not differ significantly to interaction effects of genotypes, spacings and fertilizer levels (Table 4.20a).

4.6.1.2 Potassium uptake by leaf at harvest.

Potassium uptake by leaves was significantly higher in Arka Komal (24.38 kg /ha) than Burpee Stringless (21.92 kg /ha).

Significantly higher uptake of potassium by leaf was in spacing S_1 (24.54 kg /ha). Potassium uptake by leaves was significantly lower in spacing S_2 (22.44 kg /ha) which was on par with spacing S_2 (22.48 kg/ha).

Potassium uptake by leaf was significantly higher in fertilizer level F_3 (25.43 kg /ha) followed by fertilizer level F_1 (23.31 kg /ha) and the differences among them being significant. Significantly lower uptake of potassium was in fertilizer level F_2 (20.71 kg /ha).

Potassium uptake by leaf did not differ significantly to interaction effects of genotypes, spacings and fertilizer levels (Table 4.20a).

4.6.1.3 Potassium uptake by pod at harvest.

Arka Komal showed significantly higher uptake of potassium by pod (89.94 kg /ha) than Burpee Stringless (81.86 kg /ha).

Potassium uptake by pod was significantly higher in spacing S_1 (97.70 kg /ha) followed by spacing S_2 (85.54 kg /ha) and the difference among them being significant. Significantly lowest potassium uptake by pod was in spacing S_3 (74.46 kg /ha).

Potassium uptake by pod did not differ significantly due to fertilizer levels (Table 4.20).

Interaction effects of genotypes, spacings and fertilizer levels did not influence significantly the uptake of potassium by pod (Table 4.20a).

4.6.1.4 Potassium uptake by root at harvest

Arka Komal showed significantly higher uptake of potassium by root (3.94 kg /ha) than Burpee Stringless (3.70 kg /ha).

Spacing S_3 showed significantly higher uptake of potassium by root (4.35 kg /ha) followed by spacing S_2 (3.87 kg /ha) and the differences between them being significant. Potassium uptake by root was significantly lowest in spacing S_3 (3.24 kg/ha).

Table 4.20 : Potassium uptake by various plants parts of french bean at harvest as influenced by genotypes, spacings and fertilizer levels

	Potassium uptake (kg /ha) by various plant parts				
Treatments	Stem	Leaf	Pod	Root	Total
Genotypes (G)					
G_1	22.53	24.38	89.94	3.94	140.79
G_2	18.98	21.92	81.86	3.70	126.46
S. Em ±	0.29	0.42	3.05	0.05	1.51
CD (P = 0.05)	0.80	1.31	8.44	0.14	4.20
Sapcings (S)					
S_1	23.78	24.54	97.70	4.35	150.37
S_2	20.63	22.48	85.54	3.87	132.52
S_3	17.90	22.44	74.46	3.24	118.04
S. Em ±	0.35	0.58	3.73	0.06	1.85
CD (P = 0.05)	0.97	1.61	10.34	0.17	5.14
Fertilizer levels (F)					
F_1	20.84	23.31	89.25	3.82	137.22
F_2	18.72	20.71	82.01	3.51	124.95
F_3	22.70	25.43	86.43	4.13	138.69
S. Em ±	0.35	0.58	3.73	0.06	1.85
CD (P = 0.05)	0.97	1.61	NS	0.17	5.14
CV. (%)	7.18	10.63	18.43	6.62	5.79

NS = Non-significant

Table 4.20a : Potassium uptake by various plant parts of french bean at harvest in relation to interactions of genotypes spacings and fertilizer levels

Treatments	Potassium uptake (kg ha^{-1}) by various plant parts														
	Stem			Leaf			Pod			Root			Total		
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
Genotypes (G) x Spacings (S)															
S_1	25.58	21.91		25.64	23.43		96.85	98.55		4.57	4.57		164.09	148.07	
S_2	22.68	18.57		22.89	22.06		91.83	79.25		3.93	3.81		141.22	123.70	
S_3	19.35	16.44		24.62	20.25		81.13	67.79		3.31	3.16		128.40	109.08	
S.Em ±		0.50			0.82			5.28			0.08			2.62	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Genotypes (G) x Fertilizer levels (F)															
F_1	22.61	19.07		24.56	22.06		95.18	88.32		3.93	3.70		146.29	129.59	
F_2	20.10	17.35		21.76	19.66		86.25	77.78		3.63	3.39		131.74	118.18	
F_3	24.89	20.51		26.83	24.03		88.38	84.49		4.25	4.02		155.69	133.08	
S.Em ±		0.50			0.82			5.28			0.08			2.62	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Fertilizer levels (F) x Spacings (S)															
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	24.28	20.84	26.11	24.81	21.72	27.09	103.71	97.13	92.26	4.26	3.99	4.81	157.06	143.69	167.49
S_2	20.38	19.33	22.17	23.32	20.45	23.66	87.11	79.64	89.86	3.90	3.60	4.12	134.71	123.01	139.65
S_3	17.88	15.99	19.83	21.81	19.97	25.53	76.93	69.27	77.17	3.30	2.94	3.47	122.04	108.18	126.00
S.Em ±		0.61			1.01			6.46			0.10			3.21	
CD (P = 0.05)		NS			NS			NS			NS			NS	
Genotypes (G) x Spacings (S) x Fertilizer levels (F)															
	G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2		G_1	G_2	
S_1F_1	26.02	22.55		25.89	23.72		107.87	99.56		4.51	4.00		164.30	149.83	
S_1F_2	22.16	19.52		22.76	20.67		100.81	93.45		4.16	3.82		149.89	137.49	
S_1F_3	28.56	23.67		28.28	25.91		81.88	102.65		5.05	4.58		178.10	156.90	
S_2F_1	22.41	18.34		23.81	22.84		93.63	80.60		3.96	3.85		143.81	125.62	
S_2F_2	21.08	17.58		20.48	20.41		83.70	75.58		3.69	3.51		128.95	117.08	
S_2F_3	24.54	19.81		24.38	22.95		98.16	81.57		4.15	4.08		150.89	128.41	
S_3F_1	19.39	16.33		23.99	19.63		84.03	69.82		3.33	3.26		130.75	113.34	
S_3F_2	17.05	14.94		22.04	17.90		74.24	64.31		3.04	2.84		116.38	99.98	
S_3F_3	21.59	18.06		27.83	23.23		85.11	69.24		3.55	3.39		138.07	113.93	
S.Em ±		1.49			2.46			15.83			0.25			17.93	
CD (P = 0.05)		NS			NS			NS			NS			NS	
CV (%)		7.18			10.63			18.43			6.62			5.79	

Potassium uptake by root was significantly higher in fertilizer level F_3 (4.13 kg /ha). This was followed by fertilizer level F_1 (3.82 kg/ha). Significantly lowest potassium uptake by root was in fertilizer level F_2 (3.51 kg/ha).

Potassium uptake by root did not differ significantly to the interaction effects of genotypes, spacing and fertilizer levels (Table 4.20a).

4.6.1.5 Total potassium uptake at harvest.

Arka Komal (G_1) recorded significantly higher total potassium uptake (140.79 kg /ha) than Burpee Stringless (G_2) (126.46 kg /ha).

Spacing S_1 recorded significantly higher total potassium uptake (150.37 kg /ha) followed by spacing S_2 (132.52 kg /ha) and the differences among them being significant. Significantly lowest total potassium uptake was in spacing S_3 (118.04 kg /ha).

Total potassium uptake was significantly higher in fertilizer level F_3 (138.69 kg /ha) followed by fertilizer level F_1 (137.22 kg /ha). Significantly lower uptake of total potassium was in fertilizer level F_2 (124.95 kg /ha).

Total potassium uptake did not differ significantly to interactions effects of genotypes, spacing and fertilizer levels (Table 4.20a).

4.7 Economics of use of different genotypes, spacings and fertilizer levels in french bean

The data on the economics of different genotypes, spacings and fertilizer levels in french bean are presented in Table 4.21.

Table 4.21 : Economics of use of different genotypes, spacings and fertilizer levels in french bean

	Treatments	Seed yield (q/ha)	Cost of cultivation (Rupees)	Gross income (Rupees)	Net income (Rupees)	Cost : Benefit ratio
	Genotypes					
1	Arka Komal	18.83	14484	84735	70251	1: 4.85
2	Burpee Stringless	14.86	13360	44580	31595	1: 2.36
	Spacings					
1	30 x 15 cm^2	18.94	13734	66290	52556	1: 3.82
2	30 x 20 cm^2	17.35	13104	60712	47608	1 : 3.63
3	40 x 20 cm^2	16.26	12649	56910	44261	1: 3.50
	Fertilizers levels					
1	60 : 100 :75 NPK kg/ha	18.78	13602	65730	52128	1 : 3.83
2	45 : 100 :75 NPK kg/ha	16.83	13474	58892	45418	1: 3.37
3	75 : 100 :75 NPK kg/ha	19.12	13734	66920	53186	1: 3.87

Prices of inputs and output during the period of investigation

Inputs
1) Nitrogen (Urea) = Rs. 4.00 /kg
2) Phosphorus (SSP) = Rs. 3.48 /kg
3) Potassium (MOP) = Rs. 4.50 /kg)

Output
1) Arka Komal = Rs. 45 per kg
2) Burpee Stringless = Rs. 30 per kg

The highest income (Rs.70251 ha^{-1}) and cost:benefit ratio (C:B) of 1:4.85 was in Arka Komal

In terms of economics, among the spacings, the net income (Rs.52556 ha-1) and cost : benefit ratio (C:B) (1:3.82) was highest in 30 cm x 15 cm spacing over the other spacings.

The net income (Rs. 53186 ha^{-1}) and cost:benefit ratio (1:3.87) was highest in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels (Table 4.21).

DISCUSSION

V. DISCUSSION

In an trial carried out to assess the influence of spacings and fertilizer levels on growth and yield of two frenchbean genotypes, during Kharif, 1998 carried out at Horticulture Research Station, G.K.V.K, Bangalore, the results of the investigation are discussed below.

5.1 Effect of genotypes, spacings and fertilizer levels on growth characters

5.1.1 Plant height

The genotypes were at par in the plant height at 30 and 45 DAS indicating the capability of genotypes to produce similar heights in early stages. However the significant differences were revealed at 60 DAS and at harvest indicating the variability in growth among the genotypes. Arka Komal recorded significantly higher plant height than Burpee Stringless. This may be due to genotypic variability of the genotypes.

Varying spacings had a significant effect on plant height at all stages of plant growth. Wider spacing (40x20cm^2) recorded significantly higher plant height than other spacings. This might be due to less competition for light, moisture and nutrients. These results are in agreement with the results of Singh *et al.* (1981), Dwivedi *et al.* (1994), Singh and Rajput (1995) and Singh *et al.* (1996).

Fertilizer level 75:100:75 kg NPK per ha was on par with fertilizer level 60:100:75 kg NPK per ha in the early stages of crop growth. Where as at later stages of crop growth they differed significantly. The influence of fertilizer levels was conspicuous with higher plant heights recorded in fertilizer level 75:100:75 kg NPK per ha and lower plant height recorded in fertilizer level 45:100:75 kg NPK per ha revealing the fact that the plant height is highly responsive to the added nutrients. The results are in conformity with those of Mahatanya (1977), Gupta *et al.* (1983), Chandra *et al.* (1987), Srinivas and Naik (1990), Sridhar and Suryanarayana (1992) and Dwivedi *et al.* (1994).

5.1.2 Number of leaves per plant

Number of leaves per plant was significantly higher in Arka Komal at all stages of crop growth over the Burpee Stringless. This might be due to genetic make up of genotype.

Number of leaves per plant was significantly higher in 40x20 cm^2 spacing and closely followed by 30x12 cm^2 spacing at all stages of plant growth. This might be due to less competitional stress experienced by individual plants for light, moisture and nutrients. Singh and Rajput (1995) also reported number of leaves were maximum at wider spacing (30x10 cm^2) than closer spacing (25x10 cm^2).

Number of leaves per plant differed significantly to varying fertilizer levels. Significantly higher number of leaves was in fertilizer level 75:100:75 kg NPK per ha than fertilizer level 60:100:75 kg NPK per ha and 45:100:75 kg NPK per ha. The increase in number of leaves per plant may be due to increased absorption of primary nutrients which resulted in increased synthesis of carbohydrates, which are utilized in building up of new cells. This leads to production of more number of leaves Gupta *et al.* (1983), Dahatonde *et al.* (1992), Pandey *et al.* (1994), Dwivedi *et al.* (1995), Singh and Rajput (1995) and Rana and Singh (1998) also reported similar results.

5.1.3 Number of branches per plant

Spacings had a marked influence on the number of branches per plant at all stages of plant growth. Number of branches increased with a wider spacings. This increase may be attributed to more space which helped the axiliary bud to sprout, which lead to more number of branches per plant. Similar results were also reported by Pandey *et al.* (1974), Dwivedi *et al.* (1994), Dwivedi *et al.* (1995) and Singh and Rajput (1995).

The effect of varying fertilizer levels on number of branches per plant was found to be significant at all stages of plant growth except at 30 DAS. The higher branching was in fertilizer level 75:100:75 kg NPK per ha. This increase may be due to higher levels of primary nutrients, which promoted the axiliary buds into new shoots. This is in agreement with the findings of Gupta *et al.* (1983), Kushwala (1994), Pandey *et al.* (1994), Singh and Rajput (1995), Dwivedi *et al.* (1995) and Singh *et al.* (1996).

The interaction of genotypes and spacings had a significant differences on number of branches per plant at harvest. The number of branches produced was significantly higher in $G_1 S_1$ (5.37) may be due to response of genotype to varying agroclimatic conditions.

5.1.4 Leaf area and leaf area index

Significantly higher leaf area and leaf area index was in genotype Arka Komal than Burpee Stringless at all stages of crop growth except at harvest and this may be attributed to the inheritance capacity of the genotype.

The plant spacing also had a significant influence on leaf area and leaf area index at all stages of plant growth except at harvest. Significantly higher leaf area was in spacing 40x20 cm^2 than other spacings. Increased leaf area in the wider spacing might be due to increased number of leaves per plant, more number of branches per plant and reduced competition for light, moisture and nutrients in widen spacing. The results are in conformity with those of Dwivedi *et al.* (1995) and Singh and Rajput (1995).

The varying levels of fertilizer application had a significant effect on leaf area and leaf area index. These were increased with an increase in the levels of fertilizer. This increase may be attributed to more number of leaves and branches per plant due to fertilizer application. The reduced leaf area and leaf area index at harvest may be due to senescense of leaves. Similar results were also reported by Mahatanya (1977), Chandra *et al.* (1987), Hegde and Srinivas (1989), Dwivedi *et al.* (1995) and Jasrotia and Sharma (1998).

Combined effect of genotypes and spacings and fertilizer levels and spacings had a marked effect on leaf area at 30 DAS. Interaction of G_1 S_3 and F_3 S_3 had significantly higher leaf area and more number of branches per plant. This may be due to combined effect of genotype, spacing and fertilizer levels. Sudhan (1983) also reported that the leaf area at 50 DAS was highest in 20x50 cm^2 spacing with 150 kg P_2O_5 per ha.

5.4.5 Leaf area duration

Leaf area duration was significantly higher in Arka Komal over the Burpee Stringless, which may be attributed to genetic make up of genotype.

Leaf area duration was significantly higher in wider spacing than closer spacing. The increase in leaf aread duration might be due to less competition for nutrient and light in wider spacing.

Significantly higher leaf area duration was in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels. This might be attributed to more response of the crop to the added fertilizer. These results are in conformity with the findings of Hedge and Srinivas (1989).

The combined effect of genotypes and spacings on leaf area duration was statistically significant. It was significantly higher in $G_1 S_1$ combination. This may be due to combined effect of genotype and spacing.

5.4.6 Stem girth

Stem girth was significantly higher in Arka Komal at all stages of plant growth over the Burpee Stringless. This may be due to genetic makeup of the genotype.

Significantly higher stem girth was in 40x20cm^2 spacing over the other spacings. This increase in stem girth with increase in the plant spacing might be due to less competition for light, nutrients and moisture.

Stem girth increased with increase in fertilizer levels. It was significantly higher in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels at all stages of plant growth. This increase may be attributed to response of the crop to fertilization and also signifies the higher nutrient requirement of the crop.

5.4.7 Plant spread

The difference among genotypes for the plant spread in North-South direction was significant at 30 and 45 DAS and in East-West direction at 30,45 and 65 DAS. Plant spread was significantly higher in Arka Komal over the Burpee Stringless. This may be due to inherent capacity of the genotype.

In spacing 40x20 cm^2 plant spread was significantly more in North-South direction at 30 and 40 DAS and in East-West direction at 30, 45, 60 DAS, it was on par with 30x20 cm^2 spacing in North-South direction at 30 DAS in East-West direction. Lowest plant spread was in 30x15 cm^2 spacing. Indicating that widely spaced plants had superior plant spread than closely spaced plants, because of lesser competitional stress experienced by individual plants for light, moisture and nutrients.

Significantly higher plant spread at 30 DAS was in North-South direction and at 30,45 and 60 DAS was in East-West direction in the fertilizer level 75:100:75 kg NPK per ha and lowest plant spread was in fertilizer level 45:100:75 kg NPK per ha. The fact that crop had more plant spread under higher fertilizer level may be due to more availability og nutrients and absorptive area.

5.1.8 Dry matter accumulation and distribution in different plant parts

Significantly higher total dry matter was in Arka Komal over the Burpee Stringless. This increased accumulation of dry matter by Arka Komal may be attributed to higher plant height, more number of leaves per plant and higher leaf area per plant.

Different plant spacings had a significant effect on dry matter accumulation in different plant parts except in leaf. The dry matter accumulation in leaf decreased at harvest and may be due to translocation of carbohydrates from leaves to pods and senescence of leaves. Dry matter accumulation and distribution in various plant parts increased with a wider spacing. This could be due to increased plant growth parameters because of reduced plant population. This is supported by results of Mahatanya (1977) and Halepayati and Ali (1991).

Fertilizer application had a significant influence on the dry matter accumulation and distribution in different plant parts. Significantly higher total dry matter accumulation at 60 DAS and at harvest was in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels. This increase may be attributed due to mineral nutrition. Hegde and Srinivas (1989) also reported that nitrogen up to 80 kg per ha significantly increased drymatter accumulation and distribution. Rana and Singh (1998) reported that drymatter production increased significantly with N up to 120 kg per ha and P up to 100 kg per ha.

Combined effect of genotypes and spacing on dry matter accumulation in leaf at 60 DAS and at harvest was statistically significant. Significantly higher was in G_1S_1 (7.5 and 5.78 g at 60 DAS and at harvest respectively) and lowest in G_2S_1 (5.52 and 3.74 g/plant at 60 DAS and at harvest respectively). The results indicated that high yielding genotype Arka Komal produced higher leaf dry matter under wider spacing by increased synthesis of carbohydrates which are utilized in building up of new cells.

5.2 Effect of genotypes, spacings and fertilizer levels on yield attributes.

5.2.1 Number of pods per plant and length and weight of pod.

Arka Komal produced significantly higher number of pods per plant and pod length over the Burpee stringless. This may be due to genetic make up of the genotype.

Significantly higher number of pods per plant and length and weight of pod was in 40 X 20 cm^2 spacing over the other spacings. The increased number of pods per plant and length and weight of pod in wider spacing can be attributed to lesser competition between plants for available nutrients, moisture and light. The results are in conformity with that of Pandey *et al.* (1974), Mack (1983) and Ahlawat (1996).

Fertilizer level 75:100:75 kg NPK per ha produced significantly higher number of pods per plant and length of the pod over the other fertilizer levels. This increase is attributed to increased number of leaves, more leaf area and higher number of branches per plant. These helped in increased synthesis of carbohydrate which are utilized for production and development of pods. Similar results were also reported by Pandey *et al.* (1974), Singh *et al.* (1981), Gupta *et al.* (1983) and Singh and Singh (1990).

5.2.2 Seeds per pod, Seeds per plant, Seed weight per plant

Arka Komal had recorded significantly higher seeds per pod, seeds per plant and seed weight per plant over the Burpee Stringless. This may be due to genetic make up of genotype and phenotypic effect.

Significant variation in seeds per pod, seeds per plant and seed weight per plant were recorded at harvest due to various spacings. These were significantly higher in wider spacing (40 x 20 cm^2) than closer spacings (30 x 20 cm^2 and 30 x 15 cm^2). This increase might be due to less competition for nutrients, moisture and light with wider spacing, which had less population per unit area. The results are in conformity with the findings of Mahatanya (1977), Redden *et al.* (1977), Krant (1989) and Singh *et al.* (1996).

Seed per pod was significantly influenced by the varying fertilizer levels, while seeds per plant and seed weight per plant did not differ significantly. Seeds per pod was significantly higher in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels. This may be due to higher number of leaves per plant and more leaf area per plant which helped in increased synthesis of photosynthates. This endorses the results obtained by Singh *et al.* (1981), Srinivas and Prabhakar (1985), Singh and Singh (1990) and Jesrotia and Sharma (1998).

Interaction effect of genotypes and spacing had a significant variation in seeds per pod. It was significantly higher in G_1S_3 and lowest in G_2S_1. This indicated that high yielding genotype Arka Komal produced higher seeds per pod with wider spacing and good response of the genotype to the spacings. The findings are in line with those of Jadhao (1993).

5.2.3 Test weight, shelling percentage and harvest index.

Genotype Arka Komal recorded significantly higher test weight of 100 seeds, shelling percentage and harvest index over the Burpee Stringless. The fact that this genotype had higher test weight, shelling percentage and harvest index underlines the efficiency of resource utilization and that these existed variation among genotypes entails the genetic diversity crop enjoys. This endorses the results obtained by Saini and Negi (1998).

Plant spacing of 40 x 20 cm^2 recorded significantly higher test weight and shelling percentage over the 30 x 20 cm^2 and 30 x 15 cm^2 spacings. However, test weight of 100 seeds were on par. Halepayati and Ali (1991) also reported that significant differences in hundred seed weight to varying plant population.

Application of fertilizer level 75:100:75 kg NPK per ha recorded significantly higher test weight and shelling percentage over the other fertilizer levels. The harvest index did not vary significantly to varying levels of fertilizer. The increased test weight and shelling percentage may be attributed to more photosynthetic area and more absorption of primary nutrients which helped in higher synthesis of photosynthates and were used for above parameters. Similar results were also reported by Singh and Singh (1990), Kohli *et al.* (1991) and Dwivedi *et al.* (1995).

Interaction effect of genotypes and spacings also resulted in significant variation in shelling percentage. It was significantly higher in G_1S_3 combination. Indicating that good response of genotypes to varying levels of spacings and to genetic make up of genotype.

5.2.4 Pod yield.

Significantly higher pod yield (22.09 q/ha) was in genotype Arka Komal over the Burpee Stringless (17.07 q/ha). This may be attributed to more number of leaves, increased leaf area, higher dry matter production and more number of pods per plant. This indicated that high yielding ability of the genotype and variation among genotypes. The findings are in conformation with the findings of Negi and Shekar (1993), Jadhao (1993), Ahalawat (1996) and Saini and Negi (1998).

Pod yield was significantly higher in 30 x 15 cm^2 spacing (21.39 q/ha) over the other spacings. Though individual plants produced higher pod yield under wider plant spacing over the closer spacings but the loss in yield due to reduced plant population per unit area could not be compensated and might have resulted in production of lesser pod yield per unit area. These results are in conformity with earlier findings of Pandey *et al.* (1974), Mack and Hatch (1978), Mack (1983), Ali (1989) and Dwivedi *et al.* (1994).

Pod yield increased with increase in fertilizer levels. Pod yield was significantly higher in fertilizer level 75:100:75 kg NPK per ha (20.65 q/ha) over the fertilizer levels 60:100:75 kg NPK per ha (19.50 q/ha) and 45:100:75 kg NPK per ha (18.60 q/ha). This increase in pod yield might de due to improvement in yield attributing to pods per plant, length of the pod, weight of pods increased leaf area, number of leaves per plant and dry matter production. and also to increased absorption of primary nutrients. Similar results were also reported by Asif and Grieg (1972), Sharma *et al.* (1976), Gupta *et al.* (1983), Srinivas and Rao (1984), Bhopal Singh (1987), Hedge and Srinivas (1989), Srinivas and Naik (1990), Sridhar and Suryanarayana (1992) and Jesrotia and Sharma (1998).

5.2.5 Nutrient accumulation in various plant parts.

Significant differences were recorded among genotypes in the accumulation of N, P and K in different plant parts except P in leaf and K in leaf in pod. Arka Komal accumulated more nutrients over the Burpee Stringless. The increased accumulation may be attributed to inherent characteristic of the genotype.

Significant variation in NPK accumulation in different plant parts were recorded due to varying spacing. Spacing 40 x 20 cm^2 had higher accumulation of NPK in different plant parts over the other spacings. There was a constant decrease in concentration of nutrients from wider spacing to closer spacing. This might be due to more number of plants in closer spacing and plants might have been under nutrient stress and more competition for absorption of nutrient. The results are concurrence with those obtained by Mack (1983).

Fertilizer level of 75:100:75 kg NPK per ha had higher accumulation more of nutrients in different plant parts over the fertilizer levels of 60:100:75 kg NPK per ha and 45:100:75 kg NPK per ha. This increased nutrient accumulation in different plant parts may be due to more availability of nutrients and extension of roots as indicated by higher dry matter accumulation in roots in higher fertilizer level. These results are in concurrence with the findings of Asif and Greig (1972), Mack (1983) and Srinivas and Naik (1990).

5.1.6 Nutrient Uptake.

Significantly higher uptake of NPK was in Arka Komal over the Burpee Stringless. This increased uptake may be due to genetic make up of the genotype and more responsive to the fertilizer application as indicated by higher biomass production.

Marked variation in NPK uptake was found due to different spacings. Significantly higher uptake of NPK was in 30 x 15 cm^2 spacing over the spacing 30 x 20 cm^2 and 40 x 20 cm^2. The results indicated that more nutrients were removed in closer spacing over the wider spacing. This might be due to higher plant population per unit area. Similar results were reported by Ahalwat (1996).

Significantly higher NPK uptake was in fertilizer level 75:100:75 kg NPK per ha over the fertilizer levels 60 :100:75 kg NPK per ha and 45:100:75 kg NPK per ha. The results showed that total NPK uptake increased with increase in fertilizer levels. This may be attributed to more availability of nutrient and more absorptive area of roots. Srinivas and Naik (1990), Ahlawat (1996) and Rana *et. al.* (1998) also reported the similar results.

5.1.7 Economics of different genotypes, spacings and fertilizer levels in french bean

Arka Komal gave maximum net income of Rs. 70251 per ha over the Burpee Stringless while closer spacing and highest fertilizer level tried in the trial gave the highest net returns of Rs.52556 and Rs. 53186, respectively. This may be due to higher seed yield obtained in genotype Arka Komal at closer spacing with highest fertilizer level.In terms of cost: benefit ratio, the same combination proved to be superior. Dwivedi *et al.* (1994) also obtained significantly higher net returns with 4,00,000 plant population and 80 kg N per ha. Singh and Tripathi (1994) reported that highest net return (Rs. 18,779.75 /ha) and cost: benefit ratio (1:1.09) was dose 62.5:100:100 kg NPK per ha at closer spacing (35 x 25 cm^2). Highest net returns of Rs.13405 per ha and cost : benefit ratio of 1.68 was in 30 x 10 cm^2 spacing with application of 120 kg N per ha has also been reportedby Singh and Rajput (1995).

5.9 Practical utility of the Experimental results

Among the genotypes tried in the experiment, the highest pod yield of 22.09 q per ha was in Arka Komal as compared to Burpee Stringless which produced lower yield (17.07 q/ha). Both the genotypes gave highest pod yield at closer spacing of 30 x 15 cm^2 with 2, 22, 222 plants ha^{-1}. Fertilizer level 75:100:75 kg per ha recorded significantly higher yield.

From the above results, it is concluded that the Arka Komal sown at a spacing of 30 x 15 cm^2 and application of 75:100:75 kg NPK per ha could be followed for highest and economical yield in Southern-Dry Region of Karnataka.

5.10 Future Line of Work

- Other improved genotypes may be evaluated for their performance.
- Higher levels of fertilizer could be tried for new genotypes.
- Nutrient accumulation and uptake in various plant parts at regular intervals may be estimated to understand the fertilizer requirement of the crop.
- Quality of the pods as influenced by fertilizer levels and genotypes may be estimated.

SUMMARY

SUMMARY

Studies on the effect of spacings and fertilizer levels on french bean genotypes were carried out during Kharif, 1998 at the Horticulture Research Station, GKVK, Bangalore. The sailent findings of the investigation are presented in this chapter.

6.1 Effect of fertilizer levels and spacings on growth character

Arka Komal recorded significantly highest plant height at 60 DAS and at harvest over the Burpee Stringless. Significantly highest plant height was in 40 x 20 cm^2 spacing than other spacings at all stages of plant growth. Plant height significantly increased by fertilizer 75:100: 75 kg NPK per ha at 60 DAS and at harvest.

Number of leaves per plant was significantly higher in Arka Komal over the Burpee Stringless at all stages of plant growth. Number of leaves was significantly higher in spacing 40 x 20 cm^2 over the other spacings. Fertilizer level 75:100:75 kg NPK per ha significantly increased the number of leaves per plant over the other fertilizer levels at all stages of growth.

Number of branches per plant did not differ significantly among genotypes. Spacing of 40 x 20 cm^2 recorded significantly higher number of branches per plant over the other spacings. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher number of branches per plant over the other fertilizer levels. Interaction of genotypes and spacings had a significant effect at harvest. Arka Komal with spacing of 40 x 20 cm^2 produced significantly higher number of branches per plant.

Leaf area and LAI was significantly higher in genotype Arka Komal (1070.67, 1548.40 and 2001.86 cm^2 and 1.79, 2.57 and 3.33 cm^2 at 30, 45 and 60 DAS respectively). Significantly higher leaf area (1174.95, 1741.28, 2248.53 and 1441.53 cm^2 at 30, 45, 60 and at harvest respectively) was in 40 x 20 cm^2 spacing. Leaf area and LAI was significantly higher in fertilizer level 75:100:75 kg NPK per ha over the other fertilizer levels.

Leaf area duration was significantly higher in Arka Komal over the Burpee Stringless at 30-45 DAS and 46-60 DAS. Among the different spacings, 30 x 15 cm^2 spacing recorded significantly higher leaf area duration. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher leaf area duration over the other fertilizer levels.

Genotype Arka Komal recorded significantly highest stem girth at various stages of plant growth over the Burpee Stringless. Spacing of 40 x 20 cm^2 recorded significantly highest stem girth. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher stem girth over the other fertilizer levels.

Significantly higher plant spread was in genotype Arka Komal in North to South and East to West direction at various stages of plant growth except at 60 DAS in North to South and 45 DAS in East to West direction over the Burpee Stringless. Among various spacings, the plant spread was significantly higher in 40 x 20 cm^2 spacing at all stages of plant growth except at 45 DAS. Significantly higher plant spread was in fertilizer level 75:100:75 kg NPK per ha at 30 DAS in North to South direction and at 30, 45, 60 DAS in East to West direction, which was on par with 60:100:25 kg NPK per ha. Least plant spread was in 45:100:75 kg NPK per ha..

Dry matter accumulation in different plant parts at 60 DAS and at harvest was significantly higher in Arka Komal genotype over the Burpee Stringless. Significantly higher dry matter accumulation in different plant parts was in 40 x 20 cm^2 spacing over the other spacings. Dry matter accumulation in different plant parts at 60 DAS and at harvest increased significantly by the fertility level 75:100:75 kg NPK per ha over the other fertilizer levels.

6.2 Effect of fertilizer levels and spacings on yield attributes

Arka Komal recorded significantly higher number of pods, length of pod over the Burpee Stringless. Spacing of 40 x 20 cm^2 recorded significantly higher number of pods per plant, length of pod and weight of pod over the other spacings. Number of pods and length of pod was significantly higher in fertilizer level 75:100:75 kg NPK per ha.

Pod yield was significantly highest (22.09 q/ha) in Arka Komal over the Burpee Stringless (17.07 q/ha). Significantly highest pod yield (21.39 q/ha) was in 30 x 15 cm^2. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher pod yield (20.65 q/ha) over the other fertilizer levels.

Arka Komal recorded significantly higher seeds per pod, seeds per plant and seed weight per plant over the Burpee Stringless. Significantly higher seeds per pod, seeds per plant and seed weight per plant was in 40 x 20 cm^2 spacing. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher seeds per pod over the other fertilizer levels. Combination of genotypes and spacing differed significantly for seeds per pod. It was significantly higher in Arka Komal with 40 x 20 cm^2 spacing over the other combinations.

Shelling percentage and harvest index was significantly higher in genotype Arka Komal over the Burpee Stringless. Test weight of 100 seeds was significantly higher in Arka Komal over the Burpee Stringless. Significantly higher test weight of 100 seeds and shelling percentage was in 40 x 20 cm^2 spacing over the other spacings. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher test weight of 100 seeds and shelling percentage over the other fertilizer levels. Arka Komal spaced at 40 x 20 cm^2 recorded significantly higher shelling percentage (80.50) over the other comsbinations.

6.1.3 Effect of fertilizer levels and spacings on nutrients accumulation and uptake

Nutrient accumulation in various plant parts except in leaf and pod was significantly higher in Arka Komal over the Burpee Stringless. Significantly higher nutrient accumulation in various plant parts was in 40 x 20 cm^2 spacing over the other spacings. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher nutrient accumulation in various plant parts. Interaction of genotypes and spacing differed significantly to nitrogen accumulation in root and potassium accumulation in stem. Nutrient accumulation was significantly higher in Arka Komal with 40 x 20 cm^2 spacing over the other interactions. Significantly higher nitrogen in root was in Arka Komal with fertilizer level 75:100:75 kg NPK per ha over the other combinations.

Significantly higher uptake of nutrient was in genotype Arka Komal over the Burpee Stringless. Significantly higher uptake of nutrients was in spacing 30 x 15 cm^2 over the other spacings. Fertilizer level 75:100:75 kg NPK per ha recorded significantly higher uptake of nutrients over the other fertilizer levels. Interaction of genotypes and spacings differed significantly to phosphorus uptake by leaf and root. It was significantly higher in Arka Komal with 40 x 20 cm^2 spacing.

6.1.4 Economics

In terms of economics, Arka Komal gave highest net income of Rs.70,251 ha^{-1} and Cost:Benefit (C:B) ratio of 1:4.85 over Burpee Stringless. The closer spacing of 30 x 15 cm^2 secured higher net income of Rs.52,556 ha^{-1} and Cost:Benefit ratio of 1:3.82 over other spacings. Highest net income of Rs.53,186 was obtained with the application of 75:100:75 kg NPK per ha fertilizer.

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VII. REFERENCES

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* *Original not seen*

APPENDICES

APPENDIX-I

Chemical properties of soil before planting the trail and after the harvest of the crop

	pH	EC	OC	Available N (kg/ha)	Available (P_2O_5) (kg/ha)	Available K_2O (kg/ha)
Before planting						
R-I	6.0	0.02	0.44	219.52	12.46	126.71
R-II	6.2	0.02	0.51	221.70	12.71	126.87
R-III	6.4	0.01	0.59	221.91	10.59	123.28
After the harvest						
T_1	6.2	0.02	0.40	217.29	10.46	122.91
T_2	6.1	0.05	0.42	218.56	10.71	124.12
T_3	6.1	0.04	0.37	217.59	10.75	121.52
T_4	6.3	0.02	0.44	219.85	10.76	122.67
T_5	6.2	0.04	0.37	220.34	11.83	124.22
T_6	6.0	0.03	0.33	219.22	10.49	122.52
T_7	6.3	0.02	0.37	217.29	10.59	122.87
T_8	6.5	0.03	0.44	216.56	12.36	123.62
T_9	6.3	0.05	0.37	216.86	9.78	122.87
T_{10}	6.4	0.04	0.48	217.76	10.16	125.26
T_{11}	6.3	0.02	0.43	214.49	10.26	125.86
T_{12}	6.2	0.01	0.44	217.78	9.93	124.51
T_{13}	6.6	0.03	0.55	217.92	10.46	124.60
T_{14}	6.4	0.02	0.53	216.15	10.29	122.62
T_{15}	6.2	0.04	0.48	213.91	10.38	121.07
T_{16}	6.3	0.04	0.39	218.18	11.26	122.72
T_{17}	6.0	0.03	0.52	216.40	12.39	125.53
T_{18}	6.1	0.05	0.49	217.34	10.93	121.52

R-I = Replication - I
R-II = Replication -II
R-III = Replication -III

APPENDIX -II

Meterological parameters at GKVK, Bangalore recorded during the experimental period.

Month	Relative humidity (%)	Sunshine hours	Rainfall (mm)	Mean temperature (°C) Maximum	Manimum
July 1998					
III Week	66.00	4.4	32.4	29.2	19.5
IV Week	75.00	5.1	9.4	27.9	20.1
August 1998					
I Week	70.00	4.2	66	28.1	19.2
II Week	78.00	1.7	57.4	26.5	19.5
III Week	74.50	5.1	142.2	27.9	19.6
IV Week	76.50	3.5	97.8	27.1	19.5
V Week	75.00	4.8	12.0	27.2	19.7
September 1998					
I Week	77.00	4.6	18.6	27.3	19.7
II Week	78.00	3.8	4.1	26.8	19.5
III Week	73.50	6.8	158.4	28.1	19.1
IV Week	78.00	2.0	52.6	25.9	19.2
October 1998					
I Week	80.50	1.9	103.2	27.1	19.4
II Week	80.00	4.6	115.8	27.5	19.7
III Week	73.00	5.0	12.8	26.0	17.9