Agric. Rev., 21 (3) : 141-154, 2000

PRODUCTION TECHNOLOGY OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.) CULTIVATION : A REVIEW

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ABSTRACT

This article reviews the research work done in India on various agronomic aspects of French bean cultivation. It has been found that sowing time differs greatly in different agroclimatic conditions. It is sown from March to October in different parts of the country. Similarly, different varieties are recommended for different regions. While PDR 14 (Uday) is the most suited variety in north-eastern plains during winter season, VL 63 gives higher yield in central zone during winters and in the hills when grown in summer/rainy season. Him 1 due to its short duration performs well in Haryana and Punjab conditions as it matures before the occurrence of frost. Desired plant population can be maintained by using seed rate of 100-150 kg/ha and row to row spacing of 30-45 cm depending upon location and whether the crop is meant for dry seeds or green pods. Since it does not nodulate with the help of native *rhizobia*, it responds to heavy doses of nitrogen. Its higher yield can be obtained with application of nitrogen upto 120 kg/ha and phosphorus upto 60 kg/ha. For successful cultivation, it requires assured (light but frequent) irrigations. It requires 3-4 irrigation with irrigation at 25 days after sowing being the most critical. Irrigation at IW: CPE ratio of 0.75 has been recommended. Weeds can be effectively controlled by hand weeding twice at 20 and 40 days after sowing or pre-emergence application of 0.75-1.0 kg/ha of pendimethalin 30 EC. Bean mosaic virus can be controlled by spraying Rogor 30 EC of Nuvacron 36 EC @ 1ml/litre of water. French bean can also be grown as inter crop with potato during winter season.

French bean (*Phaseolus vulgaris* L.) which is known by various names viz; rajma, rajmash, haricot bean, kindey bean, snap bean, navy bean, field bean, dry bean, pole bean etc. in different parts of the world was domesticated in Central and South America more than 6000 years ago. Wild forms of small black seeds are found in Tropical America from where it was introduced to West Africa and later to India. Common beans was spread to Europe, Africa and Asia by Spanish and Portugese and at present it is grown throughout the cooler tropics but not in the hot semi-arid or wet-humid regions (Chatterjee and Bhattacharyya, 1986).

Nutritional value : French bean is quite nutritious and potential source of protein carbohydrates and minerals. The mineral matter, crude fibre and ether extract are concentrated in seed while crude protein and energy are stored in the cotyledons (Singh *et al.* 1997). It contains about 17.5-28.7 per cent protein in the dry seeds and about 1.0-2.5 per cent protein in the green pods, 3.2-5.0 per cent mineral matter, 4.2-6.3 per cent crude fibre, 1.2-2.0 per cent crude fat and 340-450 kcal energy (Singh *et al.* 1997) besides about 61.4 per cent carbohydrates, 3.8 g ash, 425 mg phosphorus, 13.7 mg calcium, 16.7 mg iron per 100 g of edible parts and about 11 per cent water (Aykroyd and Doughty, 1973).

Uses : French bean is grown in different parts of the world for its mature dry seeds, immature/tender green or yellow pods (snap bean) and for its leaves (in Africa and Asia) to be used as vegetable. In Northern India, dry pods of French bean fetch higher price to that of other pulse crops as its vegetable preparation is considered to be one of the most nutritious and delicious dish for the 'Sunday special'. The dry seeds can also be canned and exported. Tender pods of French bean for vegetable purpose can be harvested at about 55-60 days after sowing.

Growing areas : French bean is traditionally a crop of temperate region. It is cultivated in hilly tract of Jammu & Kashmir, Himachal Pradesh (Kullu, Barot, Chamba and Shimla valley) and Uttar Pradesh. While its cultivation is mainly

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restricted to hilly region of north India, its consumption is more in the plains of north and central India, where its demand is not fully met. It is grown in Jammu & Kashmir, Himachal Pradesh, Hills of Uttar Pradesh and in some parts of Maharastra (Mahabaleshwar and Ratnagiri region) as a kharif crop and in some other parts of Maharastra, Andhra Pradesh, western and eastern Ghats and north-east plains where winters are mild and frost free as a winter crop. Recently its cultivation has been extended to northern plain zone. Chandra and Ali (1986) exploited the feasibility of growing rajmash as a potential rabi crop in the plains of north India. Possibility of its cultivation as a rabi crop in different agro-climatic situations of Bihar has been revealed by Roy Sharma *et al.* (1990). Introduction of this non traditional crop to north-eastern plains of India as a winter crop has generated lot of interest in the farming community due to its higher productivity, responsiveness to inputs and remunerative price.

Botany : It has chromosome number, 2n = 22. Germination is epigeal. It has adventitious root system. Stem is slender, twisted, angled and ribbed, more or less square in section. The flowers are white, pink or purple with reflexed standard and di-adalphous stamens and are self pollinated. Pods are borne mostly on axillary racemes. The alternate trifoliate leaves (except first two leaves) are large and often without leaflets. Pods are slender, straight or curved and terminated by a prominent beak and usually contain 4-6 seeds. Seeds are non-endospermic and vary greatly is size and colour. It does not nodulate with native *rhizobia* or commercially produced cultures.

Climatic requirements : The optimum temperature required for the growth of kidney bean is 16-24°C (Kay, 1979). It is more prone to frost than other winter pulse crops. It is also not fit for area having high temperature or year round humidity and heavy rainfall. It is also susceptible to drought.

Soil type : French bean thrives best in well drained sandy loam to loamy soils. It is highly susceptible to salinity and sodic conditions.

Sowing Time : Sowing time is the most critical factor for achieving higher productivity of French bean. Advanced or delayed sowing may cause substantial reduction in yield (Table 1) due to its senstivity to low or high temperature. High temperature during early stage of the crop is not conducive for proper growth. Advanced planting induces early flowering on account of high atmospheric temperature which ultimately leads to poor seed setting and hence low yield. On the other hand, late sown crops does not attain required vegetative growth and consequently results in poor yield. The optimum temperature required for better growth, pod set and crop maturity is between 15.6-21.1°C (Rangaswamy, 1975). Sowing of French bean on 30 March produced higher seed yield (7.96 q/ha) than 15 March sowing (7.34 q/ha) at Palampur (Chakor

Table 1 : Effect of sowing time on seed yield (q/ha) of French bean.

Sowing dates	Hisar (2)	Pandharpur (2)	Pantnagar (2)	North-east plain zone(4)	Central zone (4)
1 September	21.1	-	-	-	-
10 September	21.0	-	-	-	-
20 September	19.4	-	-	-	-
30 September	8.6	-	-	-	-
15 October	-	11.9	-	13.6	12.0
30 October	-	23.1	21.0	17.3	14.7
15 November	-	18.4	10.7	16.7	11.1
1 December	-	13.6	10.8	-	-
References	Singh *et al.* 1992	Ali and Kushwaha, 1987	Ali and Kushwaha, 1987	Ali and Lal, 1991	Ali and Lal, 1991

Figures in parenthesis are the number of years.

and Rana, 1992). At Kinnaur, April (15 or 30) sowing produced significantly higher number of pods/plant, seeds/pod, 1000 seed weight and seed yield than May (15 or 30) sowing (Saini and Negi, 1998). Tripathi *et al.* (1986), Bhardwaj *et al.* (1994) and Sahu *et al.* (1995) also reported sharp decline in yield of rajmash with delayed sowing due to poor development of yield attributes. Seed yield of French bean sown in the first (23.4 q/ha) or third (24.7 q/ha) week of May was at par with each other but significantly higher than that sown in the first week of June (16.5 q/ha) in the dry temperate region of Himachal Pradesh (Sharma *et al.* 1997).

First fortnight of September was found to be the most suitable sowing time of French bean at Hisar (Singh *et al.* 1986, Singh *et al.* 1992). Last week of September appeared to be the optimum sowing time at Ludhiana (Sekhon *et al.* 1992). End of October was reported to be the most ideal time of sowing of rajmash in the north-east plains and central zone (Ali and Kushwaha, 1987, Ali and Lal, 1991). Delay in sowing beyond 30 October reduced the seed yield to the extent of 955 and 1023 kg/ha at Pandharpur and Pantnagar, U.P., respectively (Ali and Kushwaha, 1987). Similar yield reductions of French bean due to delayed sowing were reported by Singh and Singh (1987) and Ali (1989). At Semiliguda, Orissa, sowing on 9 November recorded significantly highest green pod yield (85.1 q/ha) followed by 2 November (79.0 q) and 12 October (78.0 q) sowing (Mishra *et al.* 1998). The dry mater production decreased with delay in sowing from 1 November to 16 November and further to 1 December at Bapatala, Andhra Pradesh (Sreelatha *et al.* 1997).

Reduction in yield under late sown conditions may be attributed to poor development of yield attributes due to low minimum temperature prevailing during reproductive stages of the crop. Leaf area index, leaf area duration, crop growth rate and net assimilation rate were higher in early sowing (Sreelatha *et al.* 1997). Higher leaf area index during early sowing might be due to the optimum temperature and sunshine resulting in higher photosynthetic activity. D'Souza and Couldon (1988) reported similar results. At Ludhiana, crop sown earlier than last week of September was severely attacked by leaf crinkle virus owing to higher temperature of about 35°C; whereas in case of late sowings, maturity of the crop was considerably delayed due to low temperature and frost incidence in the month of January which damaged the crop (Sekhon *et al.* 1992). Low net assimilation rate and abscission of older leaves at later crop growth stages reduced the crop growth rate (Sreelatha *et al.* 1997).

Sowing method : Ali and Lal (1991) reported that for higher yield at Kanpur, French bean should be sown at a row to row spacing of 30 cm with plant to plant spacing of 10 cm at a depth of 8-10 cm. The maximum seed yield of French bean recorded at Bahraich, U.P. with spacing of 30 cm x 10 cm was at par with that of 25 cm x 15 cm spacing (Singh *et al.* 1996). At Kalyani, West Bengal, Chatterjee and Som (1991) recorded higher seed yield of French bean with 40 cm x 10 cm spacing as compared to 40 cm x 15 cm or 40 cm x 20 cm spacings (Table 2). However, Pande *et al.* (1974) reported that wider spacing of 60 cm produced significantly higher total green pod yield of French bean than closer spacing of 30 or 45 cm at Almora. While closure spacing of 15 cm between plants reduced the number of pods and pod weight per plant, it gave the highest yield per hectare of kindey bean as compared to wider spacings. Reduced plant to plant spacing of 7.5 cm further increased the seed yield (Appadurai *et al.* 1967). Plant to plant spacing of 4 inch increased heritability for yield

Table 2 : Effect of row spacing on the yield (q/ha) of French bean.

Spacing (cm) Row to x row	Plant to plant	Kalyani (3)	North-Eastern plain zone (4)	Central Zone (4)
40	10	28.8	-	-
40	15	20.9	-	-
40	20	18.6	-	-
30	-	-	22.7	21.8
45	-	-	21.8	18.4
60	-	-	19.8	-
References		Chattejee and Som, 1991	Ali and Lal 1991	Ali and Lal 1991

Figures in parenthesis are the number of years.

compared to 2 inch spacing indicating that decreased stress permits greater genetic expression for yield (Chung and Goulden, 1971).

Seed rate and plant population : Adequate plant population is pre-requisite for achieving good yields (Table 3). Seed rate of 120-150 kg/ha depending upon seed size was sufficient for timely sown crop (Ali and Kushwaha, 1987, Ali and Lal, 1991). Plant population of 3.33 lakh/ha was desirable for realising higher yields at most of the locations (Ali and Kushwaha, 1987, Jadhav, 1993; Ahlawat, 1996; Koli *et al.* 1996; Singh *et al.* 1996). In north-eastern Bihar, population density of 4 lakh plants/ha produced significantly higher seed yield of rajma over lower plant populations (Dwivedi *et al.* 1994). In Himachal Pradesh, only 40 kg/ha seed is recommended (Package of Practices for Kharif Crops, H.P.K.V.V., Palampur, 1993).

Seed treatment : To safeguard against several seed borne diseases, seeds should be treated with fungicides such as bavistin (carbendazim), thiram or captan (copper oxychloride) @ 3 g/kg seed.

Table 3 : Effect of plant population on the seed yield (q/ha) of French bean.

Plant population	New Delhi (2)	Amgaon(M.S.) (1)	Solapur (1)
1,66,000	-	8.3	-
2,22,000	12.4	8.9	10.7
3,33,000	13.2	8.0	10.9
4,44,000	-	-	10.0
References	Ahlawat, 1996	Jadhav, 1993	Koli *et al.*, 1996

Figures in parenthesis are the number of years.

Varieties : Uday (developed by Directorate of Pulses Research, Kanpur), HUR 15 and HUR 137 (from Banaras Hindu University, Varanasi) and VL 63 (from Vivekanand Parvtiya Krishi Anusandhanshala, Almora) are recommended for cultivation during rabi in the plains of north India (Ali and Lal, 1991, 1992). However, VL 63 can also be cultivated during kharif in the hills. The traditional indeterminate and trailing type varieties which are cultivated during kharif season in the hills are not suitable for cultivation in the plains during rabi season. Performance of different varieties under different agro-climatic conditions varies as is evident from data given in Table 4.

Varietal differences in terms of seed yield were reported by Singh and Singh (1987) and Ahlawat and Sharma (1989) and Ali and Tripathi (1988). Among 4 genotypes (PDR 14, HUR 15, HUR 137 and VL 63) recommended for winter cultivation, PDR 14 (Uday) performed better in north-east plain zone while VL 63 out yielded others in the central zone (Ali and Tripathi, 1988, Ali and Lal, 1991). Similarly, VL 63 produced significantly higher seed yield than HUR 15 and HUR 87 at Rahuri, Maharastra (Jadhav, 1993). PDR 14 recorded significantly higher seed yield than VL 63 and HUR 15 at New Delhi (Ahlawat

Table 4 : Performance of different cultivars of French bean under different agro-climatic conditions.

Cultivar	Hisar (2)	New Delhi (2)	New Delhi (2)	Amgaon (2)	Kanpur (3)	North-East zone (4)	Central zone (4)
Jawala	14.3	-	-	-	-	-	-
HIM 1	19.9	-	-	-	-	-	-
VL 63	18.0	13.0	12.3	11.4	17.7	15.5	13.0
HUR 15	-	11.3	10.7	7.9	18.6	14.8	11.2
HUR 87	-	-	-	5.8	17.6	-	-
HUR 137	-	-	-	-	-	15.2	11.3
PDR 14	-	14.8	15.5	-	19.7	17.4	11.7
Local	17.9	-		-	-	-	-
References	Singh *et al.*, 1992	Ahlawat and Sharma, 1989	Ahlawat 1996	Jadhav, 1993	Tripathi *et al.* 1986	Ali and Lal 1991	Ali and Lal 1991

Figures in parenthesis are the number of years.

and Sharma, 1989; Ahlawat 1996). Similar yield behaviour of these 3 varieties was noticed by Ali (1989) at Kanpur. Likewise at Lakhoati, Bulandshahar (U.P.), PDR 14 recorded the highest yield followed by UPF 626 and Contender (Baboo *et al.* 1998). However at Kinnaur (H.P.), HIM 2 produced significantly higher seed yield of rajmash than Jawala and local (Saini and Negi, 1998), Badiyala *et al.* (1992) and Bhardwaj *et al.* (1994) reported similar results. Likewise at Hisar, HIM 1 produced significantly higher yield as compared to Jawala, local and VL 63 (Singh *et al.* 1992). At Ludhiana also, Shekhon *et al.* (1992) reported that HIM 1 out yielded other varieties. In dry temperate zone of Himachal Pradesh (Kinnaur), French bean variety KRC 8 out yielded Jawala and HIM 1 by a significant margin (Sharma *et al.* 1997).

Crop duration is known to have profound effect on growth and yield. Higher yield of PDR 14 might be attributed to its longer duration. It also showed higher leaf area index, leaf area duration, crop growth rate and net assimilation rate than rest of the cultivars viz. HUR 142, VL 63, Contender, Chintapalli local (Sreelatha *et al.* 1997). Superiority of PDR 14 over UPF 826 and Contender was due to higher number of pods/plant, number of seeds/pod and 1000 seed weight. Number of branches and height of plants were also maximum in PDR 14 which might have provided the base for formation of pods and ultimately the yield (Baboo *et al.* 1998). However, at Hisar and Ludhiana, Him 1 out yielded other varieties as it escapes frost injury at seed filling stage due to its shorter duration leading to early maturity. On the other hand, PDR 14and HUR 87 were liable to frost injury at seed filling stage inspite of their higher yield potential (Sekhon *et al.* 1992).

Nutrient requirements

Dose : Nitrogen : French bean does not nodulate with native *rhizobia* or commercially produced cultures. Therefore, it has poor capacity to fix atmospheric nitrogen. Hence, the nitrogen requirements of French bean is different from other pulse crops which vary with genotypes (Ali and Tripathi 1988) and agro-climatic conditions (Table 5a). Application of higher doses of nitrogen especially for seed crop of French bean is imperative for realising its potential yield (Yadav and Prasad 1990, Kushwaha, 1991).

Response of nitrogen upto 60 kg/ha to French bean grown for vegtetable purpose has been reported by several workers (Sharma *et al.* 1976; Srinivas and Rao 1984; Singh, 1987). The optimum dose of nitrogen was found to be 79.7 kg/ha for targetted yield of 103.8 q/ha of vegetable beans at Bangalore (Srinivas and Rao, 1984). However, Singh (1987) realised green pod yield of 124 q/ha with application of 67.3 q N/

Table 5 (a) : Effect of nitrogen application on the seed yield (q/ha) of French bean.

N-levels (kg/ha)	Faizabad (2)	Kanpur (2)	Kanpur (2)	Solapur (1)	North-east zone (5)	Central zone (5)	Bangalore pod yield (2)	Bangalore pod yield (2)	Solan pod yield (2)
0	5.5	19.5	-	7.2	7.8	5.3	37.5	66.8	149.0
30	-	-	-	11.0	11.7	9.0	79.8		191.0
40	-	-	26.3	-	-	-	-	105.6	-
50	15.0	-	-	-	-	-	-	-	-
60	-	25.6	-	13.4	14.2	12.2	96.2	-	215.0
80	-	-	29.6					120.3	-
90	-	-	-	-	16.3	14.4	104.3	-	207.0
100	19.3	-	-	-	-	-	94.8	-	-
120	-	28.8	31.3		17.8	15.8	-	128.3	-
References	Sushant *et al.*, 1999	Saxena and Verma, 1995	Kushwaha, 1992	Koli *et al.*, 1996	Ali and Lal, 1991	Ali and Lal, 1991	Srinivas and Rao, 1984	Hegde and Srinivas, 1989	Singh, 1987

Figures in parenthesis are the number of years.

ha. At Rahuri, Maharastra, application of 60 kg N/ha produced higher seed yield of kharif French bean than its lower dose (Koli *et al.* 1996). Earlier Mech (1983) and Herath and Wahab (1984) reported similar findings. In north-east Bihar, application of 80 kg N/ha produced the maximum seed yield owing to improvement in yield attributes (Dwivedi *et al.* 1994). In Vidarbha region of Maharastra, seed yield of French bean though increased upto 120 kg N/ha during both the years, increase was significant only upto 90 kg N/ha in the first year and upto 60 kg N/ha in the second year of investigation (Dahatonde and Nalamwar, 1976). Parthibhan and Thamburaj (1991) reported similar results. Singh *et al.* (1986) reported that under agro climatic conditions of Hisar, French bean required 100 kg N/ha.

Significant improvement in pods/plant was noticed upto 120 kg N/ha whereas, seeds/pod and test weight responded to nitrogen upto 80 kg/ha at Pusa, Bihar (Nandan and Prasad, 1998). Increasing doses of nitrogen upto 120 kg/ha significantly increased the seed yield of French bean over its lower levels at Kanpur (Ali and Kushwaha, 1987; Kushwaha, 1991; 1994; Saxena and Verma, 1994; 1995; Nandanwar and Prasad, 1998; Wani *et al.* 1998). Application of 120 kg N/ha though resulted in higher yield, optimum economic dose for higher efficiency of applied nitrogen was 90 kg N/ha (Ali and Kushwaha, 1987). Saxena and Verma (1994) reported that application of 60 kg N/ha over control and 120 kg N/ha over 60 kg N/ha significantly increased the growth, yield attributes and seed yield of rajmash at Kanpur. Similarly, Baboo *et al.* (1998) reported that seed yield significantly increased with each successive increment of nitrogen upto 120 kg/ha at Lakhoati, U.P. increase in plant height and number of branches with higher levels of nitrogen might have led to improvement in yield attributes and yield of French bean. Similarly at Bahraich, seed yield increased significantly upto 120 kg N/ha as compared to lower levels though increasing trend was noticed utpo 160 kg N/ha (Singh *et al.* 1996). Total (seed+straw) nitrogen as well as phosphorus uptake (Rana *et al.* 1998) and seed yield of rajma (Rana and Singh, 1998) significantly increased with each successive increment of nitrogen upto 120 kg/ha during both years of Palampur. Nitrogen application increased the green pod yield upto 120 kg/ha though response was significant upto 40 and 80 kg N/ha in the first and second year, respectively (Hegde and Srinivas, 1989).

Phosphorus : Since French bean requires large amount of nitrogen due to its inability to nodulate, proportionate amount of available phosphorus in the soil may be required to exploit its yield potential to the maximum extent (Table 5b). Response of applied phosphorus to French bean has been reported from many places (Pande *et al.* 1974; Singh, 1987; Chandra *et al.* 1987; Ahlawat and Sharma, 1989; Baboo *et al.* 1998). Response of phosphorus to green pod yield of

Table 5 (b) : Effect of phosphorus application on the seed yield (q/ha) of French bean.

P_2O_5 (kg/ha)	Faizabad (2)	N.Delhi (2)	N.Delhi (2)	Kanpur (2)	Kalyani (3)	North-east zone (5)	Central zone (5)	Bangalore pod yield (2)	Solan pod yield (2)
0	11.3	10.6	11.2	22.3	-	12.4	9.0	47.1	154
30	13.1	-	12.8	-	-	14.0	11.5	-	-
40	-	13.8	-	-	22.8	-	-	-	201
50	-	-	-	-	-	-	-	79.8	-
60	15.5	-	14.4	25.3	-	15.2	13.6	-	-
80	-	14.8	-	-	23.5	-	-	-	205
120	-	-.	-	26.3	22.1	-	-	-	200
References	Sushant *et al.*, 1999	Ahlawat, and Verma, 1995	Ahlawat, 1996	Saxena and Verma, 1996	Chatterjee and Som, 1991	Ali and Lal, 1991	Ali and and Lal, 1991	Srinivas and Rao, 1984	Singh, 1987

Figures in parenthesis are the number of years.

French bean was observed form 40-100 kg P_2O_5/ha (Pande *et al.* 1974; Srinivas and Rao, 1984, Singh, 1987). At Hisar, 50 kg P_2O_5/ha gave the optimum yield of French bean (Singh *et al.* 1986). Increasing application of phosphorus from 40-80 kg P_2O_5/ha increased the number of pods, seeds/pod and seed yield of cv. Contender over its lower levels (Chatterjee and Som, 1991). Similarly, higher seed yields of French bean with 60 kg P_2O_5/ha (Sharma *et al.* 1976, Saxena and Verma, 1994, 1995, Sushant *et al.* 1999) and 80 kg P_2O_5/ha (Chandra *et al.* 1987) have been reported.

Ahlawat and Sharma (1989) registered maximum response with 31.7 kg P/ha at New Delhi. however, from another study, Ahlawat (1996) concluded that application utpo 26.4 kg P/ha produced the maximum yield. Ali and Lal (1991) from Kanpur also recommended application of 26.4 kg P/ha. However at Lakhoati, phosphorus application utpo 100 kg P_2O_5/ha to medium fertility soil (P, 17.2 kg/ha) significantly increased the yield attributes and seed yield (Baboo *et al.* 1998). At Palampur, also, successive increments of phosporus upto 100 kg P_2O_5/ha significantly increased the total (seed+straw) nitrogen and phoshporus uptake (Rana *et al.* 1998) and grain yield of rajma (Rana and Singh, 1998) over its lower levels during both the years on a medium fertility soil. Pande *et al.* (1974) reported that application of 125 kg P_2O_5/ha produced significantly higher green pod yield than its lower levels of 75 and 100 kgP_2O_5/ha. Fertilization of cow dung with 25 per cent DAP significantly increased the green pod yield of French bean cv. Pusa Contender over that of recommended dose of cow dung alone (Rohilla and Bujarbaruah, 1999).

Potassium : Potassium application causes accumulation of urcides in the pod walls and greater partitioning of above ground nitrogen to seeds (Thomas and Hungaria, 1988). Supplementary doses of potassium stimulate the transport of nitrogenase compounds to developing fruits and thereby increase yield (Thomas and Hungaria, 1988). Application of 60 kg K_2O/ha produced the maximum seed yield (23.6 q/ha) compared to lower levels at Kalyani (Table 5c).

Table 5(c) : Effect of potassium application on the seed yield (q/ha) of French bean.

K_2O levels (kg/ha)	Kalyani (3)	Kanpur (3)
0	-	21.5
30	21.6	-
60	23.6	24.8
90	23.2	-
120	-	24.6
References	Chatterjee and Som, 1991	Saxena and Verma, 1995

Figures in parenthesis are the number of years.

Nitrogen+Phosphorus+Potassium: Optimum combination of nitrogen + phosphorus or nitrogen + phosphorus + potassium may bring about considerable increase in yield of French bean due to their complementary effects (Table 6). Balanced application of 120 kg N+90 kg P_2O_5+60 kg K_2O per ha produced the maximum seed yield of French bean compared to its lower levels during winter season at Varanasi (Singh *et al.* 1996). Although increase in yield was significant upto 80 kg N+60 kg P_2O_5+40 kg K_2O/ha compared to lower levels of 40 kg N+30 kg P_2O_5+20 kg K_2O/ha and control, increase in uptake of nutrients (N, P and K) was significant upto 120 kg N+90 kg P_2O_5+60 kg K_2O/ha compared to lower levels (Singh *et al.* 1996). In another study, application of 120 kg N, 38.7 kgP, 49.8 kg K/ha significantly increased the seed yield by 7.5, 41.6 and 57.2 per cent over that of 80 kg N+25.8 kg P+33.2 kg K/ha, 40 kg N+12.9 kg P+16.6 kg K/ha and NPK control,

Table 6 : Effect of balanced application of nutrients on seed yield (q/ha) of French bean.

Fertilizer level $N:P_2O_5:K_2O$	Lakhaoti (2)	Varanasi (2)
0:0:0	8.1	7.9
40:30:15	11.0	-
40:30:20	-	10.8
80:60:30	17.3	-
80:60:40	-	17.5
120:90:45	18.7	-
120:90:60	-	18.6
References	Singh and Singh, 1999	Singh *et al.*, 1996

Figures in parenthesis are the number of years.

respectively (Gupta *et al.* 1996). At Samastipur, Bihar, seed yield of Rajmash with recommended dose of nutrients (80:40:20 kg/ha of $N:P_2O_5:K_2O$) was at par with that obtained with 75 per cent of the recommended dose of nutrients (Mishra *et al.* 1999). Similarly at Lakhaoti, U.P., seed yield sinificantly increased upto 80:60:30 kg $N:P_2O_5$: K_2O/ha in 1994-95 and upto 120:90:45 kg $N:P_2O_5$: K_2O/ha in 1995-96 compared to lower levels (Singh and Singh, 1999).

Time of application : Entire dose of phosphorus and half dose of nitrogen should be drilled at time of sowing (Singh *et al.* 1986; Ali and Lal, 1991) and the remaining half dose of nitrogen be top dressed after first irrigation (Tripathi *et al.* 1986; Ali and Lal, 1991) or at time of pod formation (Singh *et al.* 1986). Ali and Kushwaha (1987), however, suggested that nitrogen should be applied in 3 equal splits of planting, one month after planting i.e. after first irrigation and at flowering. Later on Kushwaha (1994) concluded that nitrogen applied in 2 equal splits (basal and at first irrigation) recorded significantly higher seed yield than other methods of nitrogen application at Kanpur. It seems that application of nitrogen at very early (entire basal) or late (at second or third irrigation) could not meet the nitrogen requirements of crop at its specific growth stages.

Soil amendments : On acidic soil of Kumaon hills, French bean produced 3.7 q/ha more pod yield with calcitic limestone than dolomitic limestone, basic slag or burnt lime (Singh and Singh, 1984). Since calcitic limestone has a greater dissolution rate than dolomitic limestone and basic slag (Barber, 1967), it might have increased the nutrient uptake and consequently the yield. The poor performance of burnt lime could be due to its caustic and hygroscopic nature causing the soil to slaken.

Water management : French bean requires frequent irrigations (Miller and Gardener, 1972; Stanhill and Smittle, 1980). Adequate moisture in the top soil layer at time of sowing is essential to ensure good germination of rajmash. Due to adventitious root system, it favourably responds to irrigations. However, light rather than heavy irrigations should be given to avoid water stagnation. Availability of nutrients to plant roots is also influenced by amount and movement of water in the soil. Favourable water balance maintained through irrigations may result in better translocation of photosynthates, greater availability of nutrients and better maintenance of cell turgidity, consequently, leading to better plant growth, yield traits and ultimately higher seed yield. (Ali and Kushwaha, 1987). Poor water supply or excessive irrigations may result in low availability or loss of nutrients. In Vidarbha region of Maharastra, the maximum seed yield of French bean was recorded when irrigations were scheduled at IW:CPE ratio of 1.2 requiring 6 irrigations (Dahatonde and Nalamwar, 1996). Green pod yield with irirgation applied at soil matric potential of -45 KPa was significantly higher than yields recorded at -65 and -85 KPa (Hegde and Srinivas, 1989). This increase was significant over all other irrigation scheduling treatments in one of the two years (Dahatonde and Nalamwar, 1996). At Palampur, irrigations at 0.9 IW: CPE ratio produced higher seed yield than irrigations applied at 0.6 and 0.3 IW : CPE ratio (Chakor and Rana, 1992). Ahlawat and Sharma (1989) and Singh and Ali (1989) advocated scheduling of irrigations at IW:CPE ratio of 0.8 requiring total of 60 cm water for optimum growth and yield of French bean. Similarly, under Kanpur conditions, IW:CPE ratio of 0.8 was found to be the most beneficial (AICPIP, 1988). In the north-east plain region of Uttar Pradesh, French bean required irrigations at IW:CPE ratio of 0.75 during winter season (Singh *et al.* 1996). At Lakhaoti, application of irrigation water at IW:CPE ratio of 0.75 registered significantly higher seed yield and higher WUE of winter sown French bean over IW:CPE ratio of 0.50 and 0.25. However, consumptive use of water was the maximum with IW:CPE ratio of 1.0 (Singh and Singh, 1999, Table 7). On sandy-loam Entisols of Pusa, Bihar, the maximum seed yield was obtained with irrigations applied at IW:CPE ratio of 0.8 or 3 irrigations applied at 25, 50

Table 7 : Effect of irrigation regimes on the seed yield (q/ha) of French bean.

Moisture level (IW:CPE ratio)	Lakhaoti (2)	Faizabad (2)	New Delhi (2)	Varanasi (2)
0.25	11.5	-	-	11.4
0.30	-	11.3	-	-
0.50	13.0	13.5	-	12.8
0.70	-	15.1	-	-
0.75	15.3	-	-	15.1
1.00	15.2	-	-	15.0
Moisture regime (mm, CPE)				
75	-	-	15.5	-
100	-	-	13.4	-
150	-	-	10.3	-
References	Singh and Singh, 1999	Sushant *et al.* 1999	Ahlawat and Sharma, 1996	Singh *et al.* 1996

Figures in parenthesis are the number of years.

and 75 DAS (Nandan and Prasad, 1998). Likewise IW:CPE ratio of 0.75 improved the yield attributes and increased seed yield at Kanpur by 31.6 per cent over IW:CPE ratio of 0.25 (Gupta *et al.* 1996). At New Delhi also, scheduling irrigation at 75 mm CPE increased the seed yield of French bean by 50.7 and 15.4 per cent over irrigations applied at 150 and 100 mm CPE, respectively (Ahlawat and Sharma, 1989). From another study, it was concluded that in north-east plain zone, 3 irrigations (25, 75 and 100 DAS) and in central region, 4 irrigations (25, 50, 75 and 100 DAS) were required with first irrigation at 25 DAS being the most critical (Ali and Lal, 1991). Irrigations applied at 75 mm CPE or at 25, 75 and 100 DAS coincided with the critical crop growth stages at New Delhi (Ahlawat and Sharma, 1989). Irrigations at IW:CPE ratio of 0.75 produced the maximum grain yield and uptake of nutrients (N, P and K) by seed and straw of French bean at Varanasi which was significantly higher than irrigations scheduled at 0.25 and 0.50 IW:CPE ratio (Singh *et al.* 1996).

Utilisation of water by different varieties may differ depending upon their growth duration. PDR 14 recorded higher consumptive use of water and water use efficiency due to its longer duration compared to HUR 15 and VL 63 (Ahlawat and Sharma, 1989). Wani *et al.* (1998) from Rahuri reported that the maximum yield of French bean was obtained with 2 irrigations, first at branching and second at flowering; however, it was at par

Table 8 (a) : Effect of irrigation regimes on the consumptive water use and water use efficiency of French bean.

Irrigation level IW:CPE ratio	Consumptive water use (mm)		Water use efficiency (kg/mm/ha)	
	Lakhaoti (2)	Faizabad (2)	Lakhaoti (2)	Faizabad (2)
0.25	156.4	-	7.31	-
0.30	-	163.2	-	6.64
0.50	194.6	199.7	6.61	6.60
0.70	-	262.9	-	5.49
0.75	265.0	-	5.65	-
1.0	309.7	-	4.88	-
References	Singh and Singh, 1999	Sushant *et al.* 1999	Singh and Singh, 1999	Sushant *et al.* 1999

Figures in parenthesis are the number of years.

Table 8(b) : Effect of fertilizer application on the consumptive water use and water use efficiency on French bean.

Nitrogen level (kg/ha)	Consumptive water use (mm)	Water use efficiency (kg/mm/ha)	
	Faizabad (2)	Faizabad (2)	Bangalore (2)
0	179.8	3.11	26.6
40	-	-	41.15
50	210.0	7.29	-
80	-	-	43.0
100	236.0	8.33	-
120	-	-	46.5
P_2O_5 levels (kg/ha)			
0	200.0	5.57	-
30	208.5	6.18	-
60	217.3	6.98	-
References	Sushant *et al.* 1999	Sushant *et al.* 1999	Hegde and Srinivas, 1989

Figures in parenthesis are the number of years.

with irrigation schedule at flowering or at 75 mm CPE. Likewise irrigation regimes and fertilizer application have profound effect on the consumptive water use and water use efficiency in French bean (Table 8a, b).

Weed Management : Since rajmash is grown under assured moisture conditions, frequent irrigations provide congenial conditions for luxuriant growth of weeds. As a result, seasonal weeds offer severe competition to the crop particularly during initial stages of growth. Ali and Kushwaha (1987) reported seed yield loss of 28.3 per cent due to weeds at Kanpur while Kumar *et al.* (1997) reported 37-59 per cent reduction in seed yield due to weeds at Lahaul Spiti, Himachal Pradesh.

Generally 1-2 weedings depending upon weed infestation are sufficient. One weeding at 30 DAS or application of pendimenthalin @ 0.75 lt or oxyflourfen @ 0.5 lt/ha as pre-emergence effectively controlled weeds at Kanpur (Ali and Kushwaha, 1987; Ali and Lal, 1991). Pre-emergence application of pendimethalin @ 1.0 lt/ha supplemented with one hand weeding at 30 DAS recorded the lowest weed density, significantly lowest weed dry weight, higher weed control efficiency (55-60%) and highest pod yield of rajmash at Lahaul Spiti (Kumar *et al.* 1997). This treatment was significantly better than application of pendimethalin or alachlor (1.0 lt/ha) alone, alachlor + one hand weeding or two hand weedings at 30 and 60 DAS (Kumar *et al.* 1997). At Varanasi, pendimethalin (1.0 lt/ha) and oxyflourfen (0.2 lt/ha) was more effective than fluchloralin (1.0 lt) or alachlor (1.0 lt) in controlling weeds and subsequently increasing yield of rajmash (Ramachandra Rao *et al.* 1997). In another experiment at Varanasi, hand weeding twice at 20 and 40 DAS produced the lowest weed dry matter, the highest weed control efficiency and maximum seed yield (Mishra *et al.* 1998a) and was significantly better than chemical weed control (Mishra *et al.* 1998b). Among herbicides, pendimethalin (1.0 lt/ha) or oxyflourfen (0.15 lt/ha) both applied as pre-emergence proved significantly superior to alachlor and fluchloralin in controlling weeds and their lower doses in increasing seed yield (Mishra *et al.* 1998a). Ali (1988) reported similar results. Danu *et al.* (1984) and Singh *et al.* (1984) reported similar effect of alachlor and fluchloralin in reducing dry weight of weeds in French bean. Hand weeding, 30 DAS, pre-emergence application of alachlor (1.5 kg/ha) or pretilachlor (0.75 kg/ha) significantly increased the seed yield of rajmash over weedy check at Samastipur

(Mishra *et al.* 1999). Pendimethalin (1.2 lt/ha) as pre-emergence recorded significantly higher yield of rajmash over metolachlor (1.0-1.5 lt/ha), alachlor (1.0 kg/ha), pendimethalin (0.9 kg/ha) and hand weeding and hoeing at 25 and 50 DAS at Kukumser, H.P. (Sharma and Sharma, 1999). Increasing plant density from 2-5 lakh plants/ha also reduced the number and dry weight of weeds and significantly increased the seed yield by 38-56 per cent (Ramachandra Rao *et al.* 1997). At Varanasi, Hand weeding at 20 and 40 DAS recorded significantly highest weed control efficiency and seed yield of French bean followed by oxyflourfen (0.225 lt/ha) and pendimethalin (1.0 lt/ha) applied as pre-emergence (Mishra *et al.* 1998a).

Insect-pest and diseases : Frenchbean is generally free from insect damage. Stored grain pests which pose threat to pulses generally do not harbour French bean seeds. However, virus can be a problem under certain situations. Bean mosaic virus (BMV) can be controlled by spraying Rogor 30 EC or Nuvacron 36 EC@ 1.0 ml/lt water, 3 weeks after sowing (Tripathi *et al.* 1986). BMV affected plants should be removed from the field. In general there is little problem of diseases, only minor incidences of common bean mosaic and yellow mosaic virus have been observed. However angular leaf spot caused by *Isariopris griseola* Sacc. is a serious disease of French bean especially during kharif season (Mohan *et al.* 1995). In Himachal Pradesh, where French bean is an important off-season vegetable crop, it is severely attacked by root rot and web blight (*Rhizoctonia solani* Kuhn), causing huge losses (Mathew *et al.* 1996). Some times there may be severe attack of rust particularly during cloudy and humid days accompanied with more morning dew during peak vegetative growth period favouring quick germination of spores of rust. Disease avoidance by adjustment of sowing time in French bean has been reported (Rangaswamy, 1975).

Intercropping studies : Intercropping is one of the possible ways to increase land productivity (Allen and Obura, 1983). Common bean which is considered to be poor nitrogen fixer is often intercropped with cereals (Adams *et al.* 1985). At Kanpur, intercropping of French bean with potato proved at efficient and remunerative system (Kushwaha and Ali, 1991). In intercropping system, potato (cv. Kufri Chandermukhi) and French bean (cv PDR 14) yielded 263 and 15 q/ha, respectively with land equivalent ratio of 1.47 as compared to sole potato yield of 326 q/ha (Ali and Kushwah, 1987). Similarly at New Delhi, planting 2 rows of French bean between paired rows of potato at 40/80 cm was more productive and efficient than either of the sole crops (Ahlawat, 1998). Similarly intercropping of Frenchbean+linseed in 4+1 row proportion was superior (LER, 1.09) to pure crop of linseed (Ahlawat, 1998).

In comparison to sole planting, yield of sorghum when intercropped with common bean is increased by 8-10 per cent. This intercropping system registered LER value of 1.64-2.12 (Kavamahanga *et al.* 1995). Common bean matured earlier than sorghum. The yield advantage for sorghum in the intercropping system might be due to less competition for moisture as well as increased availability of nitrogen from decomposed leaves of common bean falling on ground at grain filling stage of sorghum.

Correlation studies : Yield is polygenic in nature. Selection of high yielding genotypes should be based on yield components in addition to yield as a whole. Thus, knowledge of the nature and extent of character association in indispensable. Knowledge of interrelationship between yield and its components as well as among components themselves is of prime importance. The yield components in beans are believed to be essentially genetically independent whereas negative correlations are believed to arise primarily from developmentally induced relationships. Such a relationship occurs when two developing structures of a plant body compete for a common limited nutrient supply. If one structure is favoured over the other for any reason, a negative correlation may arise between them.

Although Quinones (1965) reported that seed size was not consistently correlated with yield, partial correlations between seed yield of snap bean and each yield components were high (Coyne, 1968). Correlations of pod yield with number of pods/plant (Embig and Aday, 1963; Coyne, 1968; Chung and Goulden, 1971; Shetty *et al.* 1973; Shetter *et al.* 1975; Parkash and Ram, 1981; Nandi *et al.* 1995; Samal *et al.* 1995), pod length (Setty *et al*; 1973), plant height (Parkash and Ram, 1981), number of seeds/pod (Pinchinot and Adams, 1966; Nandi *et al.* 1995) and pod girth (Nandi *et al.* 1995) were significant and positive. However, Chung and Goulden (1971) reported that correlations between yield and 100 seed weight were negative while no significant correlationship was observed between number of seeds/pod and pod yield. Days to flowering and pod weight were also negatively correlated with yield/plant (Nandi *et al.* 1995).

Number of pods/plant and number of seeds/pod exerted their major influence directly whereas, plant height and plant spread indirectly influenced the seed yield (Parkash and Ram, 1981). Yield was influenced the most by the number of pods/plant because other determinants viz; seeds/pod and seed weight were influenced by number of pods whereas seed size seemed to be dependent on size of pod i.e. larger the pod, greater would be the size of the seeds borne on it (Duarte and Adams, 1972).

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