Effect of Varieties and Irrigation Regimes on Growth, Yield and Quality of Seed in French Bean {*Phaseolus vulgaris* (L.)}

THESIS

Submitted to the

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE

In

AGRICULTURE

HORTICULTURE

VEGETABLE SCIENCE

by

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2019

CERTIFICATE- I

This is to certify that the thesis entitled **"Effect of varieties and Irrigation regimes on growth, yield and quality of seed in french bean {*Phaseolus vulgaris* (L.) }"** submitted in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE** in **Vegetable Science** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bona-fide research work carried out by Mr. **SHIVRAJ BAIRWA** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by the scholar.

(Rakesh Kumar Sharma)
Chairman of the Advisory Committee

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Member (Dr. R. Gallani) : ……..…….

Member (Dr. G.P.S. Rathore) : ……..…….....

CERTIFICATE- II

This is to certify that the thesis entitled **"Effect of varieties and Irrigation regimes on growth, yield and quality of seed in french bean {*Phaseolus vulgaris* (L.)}"** submitted by Mr. **SHIVRAJ BAIRWA** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the degree of Master of Science **AGRICULTURE** in **HORTICULTURE** in the Department of **Vegetable Science** has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination on the same.

Place: Mandsaur

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ACKNOWLEDGEMENT

Glory to God the Almighty who has not failed me. I take it to be my proud privilege to avail this opportunity to express my sincere and deep sense of gratitude to my learned advisor Dr. R. K. Sharma, Asst. Prof., Department of Vegetable Science for his stimulating guidance, constructive suggestions, keen and sustained interest and incessant encouragement bestowed during the entire period of investigation, as well as critically going through the manuscript.

I am gratified to record sincere thanks to the members of the advisory committee; Dr. S. S. Kushwah, Asst. Prof. and Head, Department of Vegetable Science, Dr. R. Gallani, Asst. Prof., Department of soil science, Dr. G.P.S. Rathore, Prof., Department of Agricultural Statistics for their generous gestures and valuable suggestions in planning and execution of this study.

I am privileged to express sincere and deep sense of gratitude to Dr. S. K. Rao, Hon'ble Vice Chancellor, R.V.S.K.V.V., Gwalior and Dr. A. K. Singh, Director of Instruction, R.V.S.K.V.V., Gwalior. With deepest sense of humility and gratefulness, I feel myself duly bound to express my heartfelt and sincere thanks to Dr. S. N. Mishra, Dean, College of Horticulture, Mandsaur for his due attention and encouragement during the study period and also for providing me the necessary facilities during the course of study.

Words cannot express the heartfelt gratitude for my most revered my parent Sh. Ramcharan Bairwa, Mother Smt. Kanchan Bai. Sister Gayatri and brother Shivraj Endoliya, My lovely Wife Smt. Sunita Endoliya, Little brother Chotu Endoliya, Smt. Sheela Endoliya, Manish, Nidhi, and all members of my family.

Words can hardly register the sincere and heartfelt feeling, which I have for Mr. p. and my batch mates Kalu, Ravindra, Devsingh, Lakhan, Aishwaryia, Sunil, Sonal, Birju, Kulendra, Tolsingh, K. K. Rajodiya my Lovely senior Dhanraj sir, M. Nagar sir. Toran sir, J. Bhandhri Sir, G. Singh Chohan Sir, L. Meena Sir, my Lovely juniors specially Ashok, Saran, Sudeep, Ankit, Vijay, Gabru, C. Mouli, N. Ready, Dhiksha, Kaveri, Radu, Mayur, Akhilesh, Gopal, Sanat, Pravin, Dixit, Arun, Ganpat, Anup, for their kind, co-operation and help as when needed.

I also place on record, my sense of gratitude to one and all who, directly or indirectly have lent their helping hands in this venture.

Place – Mandsaur

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CHAPTER- I

INTRODUCTION

Chapter – I

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most important leguminous short duration vegetable crops. It is probably a native of South America and is undoubtedly of ancient origin. It is also known as rajmah, rajma, kidney bean, haricot bean, field bean, snap bean, navy bean, dry bean etc. In India, it is mainly grown as a winter crop in Jammu and Kashmir, Himachal Pradesh, Madhya Pradesh, Uttar Pradesh and some parts of Andhra pradesh, Maharastra, Western and Eastern Ghats and North-East plains where winters are mild and frost free.

It is grown for the tender green beans and dry beans (Rajmah). It is used for its fresh pods or dry seeds which are a good source of vitamins A and C and calcium, phosphorus and iron, with a highly nutritive value in human nutrition in the world. Each 100 g edible fresh pods contain 91.4% water, 1.7% protein, 0.1% fat, 4.5 % carbohydrates, 50 mg calcium, 28 mg phosphorus, and 1.7 mg iron, whereas each 100 g dry seed contain 9.6% water, 24.9% protein, 0.8% fat, 60% carbohydrates, 60 mg calcium, 433 mg phosphorus, and 2.7 mg iron (Nath and Swamy, 2016).

It is largely grown in hilly areas of Himachal Pradesh, Jammu and Kashmir and north-eastern states during summer and winter and autumn crop in parts of Utter Pradesh, Maharashtra, Karnataka and Andhra Pradesh. In northern plains, it is cultivated on a limited scale as autumn or spring crop, because of susceptibility to low as well as high temperatures (Chadha, 2001)

Water is the most important factor limiting horizontal and vertical expansion in the production of different crops. Crop yield and quality are affected by available water in the soil. It is highly desirable to obtain higher yield using the least possible quantity of water. Increasing number of irrigations, levels of field capacity, irrigation amounts, pan evaporation ratios and/ or potential evapotranspiration (ETo) up to the maximum level increased growth parameters;

i.e. plant height, number of branches per plant, leaf area, total plant dry matter, number of flowers and fruit setting percentage on peas and on beans (Ei-Noemani *et al.*, 2015).

The lack of proper irrigation scheduling decisions and appropriate evaluation of their performance and economic impacts at farm level are the main constraints for adoption of efficient irrigation strategies. Deficit irrigation technique is an irrigation scheduling strategy in which only a fraction of seasonal net crop water requirement is achieved through applied irrigation water. It matches the level of irrigation, the amount of land and the crop mix, which maximizes the benefits of irrigation. Correct application of deficit irrigation requires the understanding of yield and economic impact of reduction of harvested produce (Lado *et al*., 2017)

Thus, the amount of irrigation applied at the developmental (vegetative and reproductive) stages, affect the bean production in that plant growth and yield are often reduced by periods of water stress. Efficient use of water in any irrigation systems is vital especially in arid and semi-arid regions. Drought occurs in many parts of the world in every year; often with devastating effects on crop production. As the water supply is limited worldwide, there is a need of water saving in irrigation and thus, deficit irrigation should be applied (Simsek *et al*., 2011).

Irrigation scheduling methods based on pan evaporation are widely used because of their easy applications. With available pan coefficient in hand, pan evaporation (Class A Pan) can be used in the arrangement of irrigation programs.

Beans are rapidly growing plants and very sensitive to soil water conditions and quality, so yield can suffer greatly from even brief periods of water shortage. Under such conditions, water stress reduces yield of the crop, but cultivars vary in the degree of reduction Water management in green bean production is important at all stages of plant development due to its influence on growth yield and yield quality (Smesrud *et al.*, 1997) (Marzouk, *et al.,* 2016).

Irrigation level also plays an important role on water utilized and consequently on crop yield and quality. The vegetative growth and yield of faba bean was reduced when plants were subjected to drought event (Hegab *et al*., 2014).

French bean is the most responsive pulse crop for irrigation due to its shallow root system and high nutrient requirement. As it does not grow well in moisture deficient areas, assured irrigation is a pre-requisite for its successful cultivation (Chaudhari *et al.*, 2008). Irrational use of water and lack of appropriate tools for regulated and uniform application of the desired quantity of water at the appropriate time are the major causes of low water-use efficiency at the field level. Irrigation scheduling through an IW/CPE ratio approach is relatively more practical than other meteorological approaches (Kumar and Singh, 2014).

Keeping in view the above facts, an experiment entitled “Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (*Phaseolus vulgaris* L.)” will be conducted during 2018-19 with the following objectives:

1. To study the performance of french bean varieties.
2. To assess the effect of irrigation regimes on growth, yield and quality of seed in french bean.
3. To determine the combined effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean.

CHAPTER - II

REVIEW OF LITERATURE

Chapter-II

REVIEW OF LITERATURE

The growth, yield and quality of french bean, besides genetic factors largely depend upon climate and management practices, such as time of sowing, nutrients, irrigation, spacing, plant protection etc. A brief resume of research work done by various scientists in India and abroad on “Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (*Phaseolus vulgaris* L.)” and related aspects has been briefly reviewed and presented in chronological order in this chapter.

1. **Effect of irrigation regimes**
2. **Effect of varieties**
3. **Combined effect of irrigation regimes and varieties**

2.1 Effect of Irrigation regimes

Dapaah *et al.* (2000) Examined growth and yield of pinto beans (*Phaseolus vulgaris* L.) cv. Othello in response to a total of six sowing dates (from October to December) and irrigation was treatment induces two irrigation treatments (nil and full) were combined with two sowing dates (27 October and 24 November). In 1995} 96, Othello was examined under two irrigation treatments (nil and full) and four sowing dates (1 November, 15 November, 29 November and 13 December). The total rainfall for the two seasons was 50% and 60% of the long-term average, respectively. The mean temperatures for the seasons were similar to the long-term average. Both irrigation and sowing date had a marked effect on growth and seed yield. Averaged over both seasons, seed yield for fully irrigated crops was 337 g/m, *c*. 50 % higher than the yield of unirrigated crops. The irrigated crops yielded more than the unirrigated crops because they attained greater canopy closure, intercepting 84±95% of incident radiation. They also had on the average 47% higher leaf area duration (LAD), 72% higher maximum leaf area index (LAI) and greater utilization coefficient. The mid- to late November-sown crops yielded more than the late October to early

November and December-sown crops because the leaf area of the former increased most rapidly, achieved a higher maximum LAI and LAD and consequently intercepted more photosynthetically active radiation (PAR). They also had faster pod growth rates and 26% of stored assimilates contributed to pod growth compared with 13% in late October to early November and 5% in December-sown crops. The results showed that pinto beans can grow and yield well in Canterbury, and that a yield advantage could be obtained when sown in mid- to late November and with irrigation.

Abdel-Mawgoud (2006) investigated the interactive effects of different irrigation levels and compost applications on the growth, yield and quality of green bean crop. Green bean seeds (*Phaseolus vulgaris* L.) cv. Pulista were sown in the two successive season of 2003-2004 and 2004-2005. Three irrigation levels (80, 100 and 120% of class A-pan) combined with three application rates of compost (10, 15 and 20 m^3/fed.) were applied. Vegetative growth parameters as well as yield components responded positively to the individual effects of increasing the irrigation level and compost application rates. Mineral contents in the leaves showed also similar positive response to the increment in both factors. Plant height, number of leaves as wellas fresh and dry weights of the plant showed positive correlations with both factors. Total weight of pod yield and quality also responded positively to both factors. The interactive effect of both factors seemed to be cumulative. It could be concluded that application of compost to newly reclaimed lands improves growth of green bean and enhances different applied water regimes.

Malik *et al.* (2006) evaluated the interactive effects of irrigation and phosphorus on green gram (*Vigna radiata* L.). Four irrigation levels (I_0 = No irrigation), (I_1 = irrigation at vegetative stage), (I_2 = irrigation at vegetative and flowering stage), (I_3 = irrigation at vegetative, flowering and pod formation stage) and five phosphorus doses (P_0 = 0, P_1 = 20, P_2 = 40, P_3 = 60 and P_4 = 80 kg ha^{-1}) were arranged in a split plot design with four replications. Irrigation treatments exhibited positive effects on yield and yield components. Less than two and more than two irrigations were not economically beneficial. Phosphorus application @

40 kg P_2O_5 ha^{-1} affected the crop positively, below and above this level left non-significant effect. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were most effective. Rest of the combinations remained statistically non-significant to each other. It may be concluded that green gram can be successfully grown under limited water supply when at least two irrigations are given with phosphorus at 40 kg P_2O_5 ha^{-1}. The response of the crop was consistent during both the seasons; however, it was better during the first season than during the second one, which could be attributed to better climatic conditions.

Webber *et al.* (2006) Studied water use efficiency of common bean green gram grour used alternate furrow and deficit irrigation The WUE of two water saving irrigation technologies were evaluated for two legumes, grown as a second crop, in the Fergana Valley of Uzbekistan. Conventional and alternate furrow irrigation and three irrigation schedules were used to irrigate food legumes in a field experiment conducted over two growing seasons (2003 and 2004) after winter wheat harvest. The treatments consisted of factorial combinations of three factors, organized following a split-plot randomized complete block design with four blocks: three irrigation schedules (recommended, moderate and severe depletions) as the main plot factor and combinations of the two irrigation strategies (conventional and alternate furrow irrigation) and two crops (green gram and common bean) as the two sub-plot treatment. The WUE was quantified for commercial yield, above ground biomass and root biomass per unit of water consumed by the crop. The results of this study indicate the WUE for both commercial yield and biomass were approximately twice as high for green gram as bean. Conversely, the water use efficiency for root biomass in bean (0.15 kg m^{-3}) was slightly higher than in green gram (0.13 kg m^{-3}). WUE increased in green gram when deficit irrigation or alternate furrow irrigation were practiced, whereas it remained constant in bean for all treatment combinations. These results suggest that common bean is not as well suited to water scarce conditions as green gram. Alternate furrow irrigation and deficit irrigation are appropriate methods to increase WUE, allowing application of less irrigation water, particularly, for green gram production.

Chaudhari *et al.* (2008) evaluated the response of French bean (*Phaseolus vulgaris* L.) to irrigation schedules, phosphorus levels and phosphorus solubiliser application in Vertisols. Scheduling of irrigation at IW/CPE 1.0 produced optimum mean yield of French bean. Application of recommended dose of phosphorus (RDF) (F_1) and 75% RDP + phosphorus solublizing bacteria (F_3) remained comparable and produced at par French bean pod yield. Mean value of consumptive use of water was maximum at IW/CPE of 1.2 and minimum at IW/CPE of 0.6.

Sezen et al. (2008) investigated the effects of different irrigation regimes on yield and quality of green beans (*Phaselous vulgaris* L.) irrigated with a drip irrigation system under field conditions in the Mediterranean region of Turkey were evaluated along two years. Irrigation regimes consisted of four irrigation intervals based on four levels of cumulative pan evaporation (Epan) values (I_1: 15; I_2: 30; I_3: 45 and I_4: 60 mm); irrigations occurred on the respective treatments when Epan reached target values, and three plant–pan coefficients as for irrigation levels (Kcp_1 = 0.50, Kcp_2 = 0.75 and Kcp_3 = 1.00). Irrigation intervals varied from 2 to 4 days in I_1, 5 to 7 days in I_2, 8 to 10 days in I_3 and 10 to 12 days in I_4 treatments in 2004 and 2005 growing seasons Both irrigation levels and intervals significantly affected the green bean yields. Maximum and minimum yields were obtained from the I_1Kcp_3 and I_4Kcp_1 treatments as 24,320 and 14,200 kg ha^{-1} in the first, and 23,850 and 13,210 kg ha^{-1} in the second experimental year, respectively. As the Kcp value decreased the total yields in each irrigation interval also decreased. However, with the longer irrigation interval (I_4), lower yields were obtained with all Kcp coefficients. Seasonal water use (ET) values in the treatments varied from 276 mm in I_4Kcp_1 to 400 mm in I_1Kcp_3 in the first experimental year, and from 365 mm in I_4Kcp_1 to 472 mm in I_1Kcp_3 in the second experimental year. Significant linear relations were found between green bean yield and seasonal ET for each experimental year. Irrigation intervals resulted in similar water use in the treatments with the same Kcp value. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) values were significantly influenced by the irrigation intervals and plant–pan coefficients.

WUE ranged from 4.33 kg m^{-3} in I_4Kcp_3 to 6.08 kg m^{-3} in I_1Kcp_3 in 2004, and varied from 3.62 kg m^{-3} in I_4Kcp_1 to 5.43 kg m^{-3} in I_2Kcp_2 in the 2005 growing season. Maximum IWUE was observed in I_2Kcp_1 (6.16 kg m^{-3}), and minimum IWUE was in I_4Kcp_3 treatment (3.83 kg m^{-3}) in the experimental years. Both irrigation levels and irrigation frequencies had significantly different effects on quality parameters such as fresh bean length, width, number of seed per pod and 100 fresh bean weights. In conclusion, I_1Kcp_3 irrigation regime is recommended for field grown green beans under the Mediterranean conditions in order to attain higher yields with improved quality.

Patel *et al.* (2010) Studies the effect of irrigation levels based on IW:CPE ratios (0.6, 0.8 and 1.0) and six levels of time of nitrogen applications (100% basal, 50% N as basal + 50% N at branching, 50% N as basal + 25% N at branching + 25% N at flowering, 50% N as basal + 25% N at branching + 25% N at podding, 50% N as basal + 25% N at flowering + 25% N at podding, 25% N as basal + 25% N at branching + 25% N at flowering + 25% at podding stage) on seed yield, straw yield and economy of French bean (*Phaseolus vulgaris* L.). Scheduling of irrigation at an IW:CPE ratio of 1.0 recorded significantly higher seed and straw yield, net return and benefit : cost ratio during both the years of study and also in the pooled results. Among the time of nitrogen applications, application of half nitrogen as basal and remaining half nitrogen at branching stage was proved to be the most effective mode of nitrogen application by recording the highest seed yield, straw yield, net return and benefit: cost ratio.

El-Mogy *et al*. (2012) Evaluated the effects of pulse irrigation on yield and nutritional elements of green beans (*Phaselous vulgaris* L.), irrigated with a subsurface drip irrigation system, The irrigation system consisted of four irrigation treatments based on the number of pulses which ranged from T_1 where the irrigation water requirement applied at one time to T_4 where the irrigation water requirement applied using four pulses. Maximum and minimum yields were obtained from T_4 and T_1 treatments as 4.83 and 3.78 t/fed. in the first experimental year 2008 and 4.73 and 4.06 t/fed. in the second experimental year 2009, respectively. WUE ranged from 4.59 kg/ m^3 in T_1 to 6.84 kg/ m^3 in T_4 for

the first experimental year and varied from 4.44 kg/ m^3 in T_1 to 6.64 kg/ m^3 in T_4 in the second experimental year. Results showed that the vegetative growth of green bean plants (plant height, number of leaves, plant fresh weight, plant dry weight, total leaf area as well as chlorophyll content) were improved by increasing number of pulses per each irrigation. It was found that the highest concentration of all determined nutrient elements was obtained in the high pulse irrigation T_4, while the lowest concentration was obtained in the low pulse irrigation T_1.

Tyagi *et at*. (2012) conducted a field experiment on sandy loam soil analysing low in N and medium in P and K during winter season of 2004-05 and 2005-06 at Indian Agricultural Research Institute, New Delhi. The treatments comprised 5 irrigation levels (irrigation at critical stages of potato (*Solanum tuberosum* L.), irrigation at critical stages of French bean (*Phaseolus vulgaris* L.), and irrigation at 0.8, 1.2 and 1.6 IW/CPE ratio) as main plots and 3 cropping systems (sole potato, sole French bean and potato + French bean in 2:3 row ratio) Irrigation at IW/CPE ratio of 1.6 produced the highest tuber yield followed by irrigation at 1.2 IW/CPE ratio, while the lowest tuber yield was achieved with irrigation at 0.8 IW/CPE ratio. Although the tuber yield with irrigation applied at critical growth stages (CGS) of potato was significantly lower than with IW/CPE ratio of 1.6, but the water use efficiency (WUE) with CGS of potato was higher. In French bean, both seed yield and WUE was higher with irrigation at CGS of French bean than that obtained with the irrigation at all the three IW/CPE ratios studied. Tuber yield of potato was higher in sole potato than when intercropped with French bean. Potato + French bean intercropping system recorded much higher B:C ratio (2.53) as against 1.54 with sole potato and 1.97 with sole French bean.

Singh *et al.* (2014) carried out a field experiment using Rajmash as attest crop during two consecutive years that is, 2008-2009 and 2009-2010. The experiment was designed using spit plot technique. Method of sowing (flat and raised bed) and moisture regime (0.6, 0.8, and 1.0 IW/CPE) was the main nplot factor and four nutrient supply systems that is, 100% recommended dose of

Nitrogen (NPK) fertilizer – RDF (120:60:40 kg/ha supplied through standard grade Urea (46%N), DAP (46 and 18% P & N) and) 75% RDF +25% through FYM, 75% RDF + 25% BY Bio compost and 75% through NPK + 25% N by Azotobactor was taken as sub plot, A total of 24 treatment combinations were replicated three times. Various growth parameters e.g. plant height (cm), number of branches per plant and leaf area index (%), dry matter accumulation (g/plant) at 30, 60, and 90 and at harvest stage as well as grain and straw yield were recorded.

El-Noemani *et al.* (2015) Exhibited that increasing irrigation up to 80% of available soil water (A.W) increased significantly vegetative growth (plant height, branches no., leaves area, and pods no. as well as dry matter of stems, leaves, pods, roots and total plant and green pods yields kg/fed. Pod length exhibited its highest significant value when plants were subjected to (80% A.W.), while irrigation at 60 or 40% of available water (A.W.) showed the lowest values of the growth parameters of bean plants. Generally, subsurface drip irrigation (SSDI) with 80% of available water (A.W.) increased significantly vegetative growth, yield and pod quality as well as dry matter of stem, leaves, roots, pods and total plant. It could be concluded that in both bean varieties, the interaction influence was significant on green pods yield kg./ fed and pod thickness, whereas pod weight was not significantly affected by the interaction for the two varieties. A similar trend of the interaction in both varieties was obtained in pod quality indicating that quality parameters showed their highest significant values when bean plants were irrigated by subsurface drip irrigation system (SSDI) at 80 % of available water. Moreover, the aforementioned characters showed their lowest interaction values parameters when bean plants were irrigated by surface drip irrigation system (SDI) at 40 % of the available water. The effect of interaction on pod weight was not significant for the two varieties as well as pod length for Contender variety.

Gopal *et al.* (2015) studied the effect of moisture regimes and fertility levels on growth and yield of French bean, *Phaseolus vulgaris* under late sown condition. Moisture regimes at 0.9 IW/CPE ratio was significantly better than

other moisture regimes in terms of yield attributes and yield. However water use efficiency was lowest at 0.7 IW/CPE ratio. Fertilizer application of 150 kg N + FYM @ 5 tons/ha resulted in higher grain yield. Both irrigation and fertilizers improved the growth and yield parameters markedly.

Abdelgadir (2016) carried out a field trial was carried out for three consecutive seasons (2004-2005, 2005-2006 and 2006-2007) to study the increase of faba bean productivity and improve soil properties by using farm yard manure and irrigation regimes on reclaimed high terrace soils (Arid sols). The experiment consists of three irrigation regimes, which are (after 7, 14 and 21 days), and application of 0.0 and 10 ton/ha farmyard manure (FYM). Superphosphate at a rate of {½ P=20 kg P/Fed) was applied to all treatments at sowing. One faba bean variety was used namely SM-L. Data on grain yield and biomass show that there were significant differences in grain yield between the two FYM levels effects. The irrigation regime also significantly affected grain yield. As expected the addition of FYM to the soils improved grain yield in all irrigated periods compare to without manure (0 FYM), and also in 7 days irrigated were higher than in 14 and 21 irrigated periods. The reduction of faba bean grain yield from 14 to 7 days and from 21 to 7 irrigated days ranges about 5% and 35% for 0 ton/ha FYM treatments, and about 19% and 57% for 10 ton/ha FYM treatments, respectively. However, addition of 10 ton/ha FYM (M1) at irrigation every 7 days interval was significantly higher than in 14 and 21 irrigated days regimes. It can be concluded that the highest faba bean yield was observed in to use 10 ton/ha FYM with irrigation period (every 7 days interval) in the soil reclamation of saline soils and to improved crop productivity.

Asemanrafat and Honar (2017) conducted a field experiment to study the effects of different irrigation regimes and plant density on yield component and protein concentration and crop water stress index (CWSI), The first factor of variables was the effects of 4 irrigation levels 120% (I_1), 100% (I_2), 80% (I_3) and 60% (I_4) of Standard evapotranspiration and the second factor was the spacing of 5 cm (D_1), 10 cm (D_2) and 15 cm (D_3) between plants within a row. Results indicate that the number of pods in each plant and the grains in each pod

decreased when density increased, but the hundred-grains-weight and the height of bean plants increased. When irrigation increased, various increases were observed in the yield, the number of pods in each plant, the grains in each pod, the hundred-grains-weight and the height of bean plants, but the grain protein decreased. Protein concentration increased with more severe water deficit in the soil. The protein concentration directly correlated with total irrigation water during the growing season (TI) and the exponential equation $P=33^* e^{-4E^{-04}TI}$ can be used for protein concentration prediction. The effect of the irrigation water was significant and CWSI increased with increased soil water deficit. The effect of the density for CWSI was not significant. Grain yield (GY) directly correlated with CWSI and the exponential equation, GY=696.2(CWSI)-0.51 can be used for the prediction of grain yield. The CWSI value is useful for evaluating crop water stress in beans and thus it could be useful in timing the irrigation. Results of this research indicate that yield components such as height of bean plant, the number of pods in each plant and the number of grains in each pod were significantly different by applying the different irrigation strategies at the three different lengths of plant spacing within a row.

Gupta *et al*. (2017) Conducted a field experiment was conducted to study the effect of irrigation regimes and nutrient levels on growth, yield, quality, economics and water use efficiency (WUE) of broad bean. Treatments included three irrigation regimes, viz. I_1 (IW/CPE=1.00), I_2 (IW/CPE=0.75), I_3 (IW/CPE=0.50) and three nutrient levels, viz. F_1 (15:40:30 kg NPK/ha), F_2 (30:60:45 kg NPK/ha) and F_3 (45:80:60 kg NPK/ha). Results indicated that irrigation level I_1 (IW/CPE=1.00) recorded maximum plant height, number of tillers/plant, number of leaves/plant, leaf area/plant, most delayed 50% flowering and pod maturity, maximum length of pod, number of pod/plant, number of seeds/pod, weight of 10 pods, pod yield/plant, pod yield/hr and fibre content in pod. It was followed by I_2 (IW/CPE=0.75). Highest protein content was found under I_3 (IW/CPE=0.50). WUE decreased with higher irrigation regimes and was observed lowest with I_1 (IW/CPE=1.00). Among nutrient levels, F_3 (45:80:60 kg NPK/ha) registered maximum growth, phenological, yield attributes and yield as

well as protein and fiber content. It has also recorded highest WUE. Interactive effect of irrigation regimes and nutrient levels showed highest growth and yield attributes as well as yield with I_1F_3. Highest WUE was recorded with I_3F_2 which was at par to I_3F_3. Maximum gross return (154 770/ha), net return (` 113 820/ ha) and benefit:cost ratio (2.77) was obtained with application of I_1F_3.

Lado *et at*. (2017) investigated the effect of deficit irrigation scheduling on yield and water relation of French bean (*Phaseolus Valgaris* L). The modified FAO Peneman Montieth Method was used to calculate ETo by adapting ETo calculator, crop coefficient was used to calculate evapo transpiration ETc, the water application levels were 100% of evapotranspiration (ETc), 80% ETc, 60%ETc, and 40%Etc. Based on these irrigation levels. The experiment was laid out in RCBD with four treatments and three replications. Data collection during the experiment was irrigation depth and crop data (pod yield), Crop water use and Irrigation water use. The deficit irrigation levels applied throughout the growing season of French bean had significantly ($P < 0.001$) affected pod weight .From the result the highest yield was found in treatment 100%ETc (10.008 t/h) and the lowest yield was found in treatment 40%ETc (3.203 t/ha) the deficit irrigation was throughout the season except crop establishment (initial stage), the highest and lowest crop water use efficiency (3.07 Kg/m^3) and (2.25 Kg/m^3) were found in 80%ETc and 40%ETc. and the highest irrigation water use efficiency was 2.76 and 2.03) in treatments 80%%ETc and 40% ETc). Therefore in water scars areas irrigation water for French beans can be reduced by 20% water requirement with less effect in yield reduction.

Saleh *et al.* (2018) conducted a study in an environmentally controlled greenhouse to evaluate two green bean cultivars, ‘Bronco’ and ‘Paulista’, under three application volumes of irrigation water based on replacing 100, 80, and 60% of evapotranspiration (ET). The results showed that there were no differences between 80% ET and 100% ET for most parameters. In addition, 80% of ET increased the pod yield and improved the pod parameters and chemical composition. Therefore, this irrigation treatment can increase green bean productivity and improve pod quality. Reducing water application from 100

to 60% of ET progressively increased WUE. The 'Bronco' cultivar had a higher plant height, pod yield, WUE, pod weight, pod diameter, and total fiber amount than 'Paulista', while the 'Paulista' cultivar was superior in total chlorophyll, number of pods per plant, pod length, P, Ca, Mg, Fe, Cu, protein, vitamin C, titratable acid, and soluble sugar.

2.2 Effect of varieties

Moniruzzaman *et al.* (2007) conducted a field experiment on French bean having three varieties (BARI Jhar Seem-1, BARI Jhar Seem-2 and Local) and six sowing dates at 10 days interval from November 01 to December 20) to find out the suitable variety and optimum sowing date for getting higher pod yield. Both the varieties of BARI Jhar Seem-1 and BARI Jhar Seem-2 yielded higher from local variety but the first two varieties were statistically at par in respect of pod yield. November 10 sowing was statistically at par with November 20 sowing gave the highest pod yield of French bean. BARI Jhar Seem –1and BARI Jhar Seem-2 produced maximum pod yield of French bean when sown on either November 10 or November 20.

Yoldas *et al.* (2007) assessed the effect of windbreak and sowing dates on growth and yield of bean varieties; Amboto, Gina, Nashau, Volare. Two different treatments of cultural practices (windbreak/no windbreak) were applied all cultivars and sowing dates. Seeds were sown in well prepared soil on 23.07.2004 and 27.08.2004 in 1^{st} year and 29.07.2005 and 29.08.2005 in 2^{nd} year. Results are showed that sowing date, variety and windbreak generally exhibited significant positive influence on growth parameters and yield components. Yield was significantly decreased with Later sowing that in all 2 years of research. Significantly better results were obtained in treatments when was used WB. Amboto performed better compared with other three varieties, mostly due to more yield per ha and per plant. Hence, Amboto is recommended for general cultivation of bean and SD_1 was the optimum sowing date of bean for Odemis condition.

Maske *et at* (2009) conducted an experiment to investigate the performance of french bean (*Phaseolus vulgaris* L.) genotypes under different fertility levels. Each replication consisted of twelve treatment combinations of four varieties *i.e.* Contender, Waghya, HPR-35, Varun and three fertility levels 90:45:45 NPK kg.ha^{-1}, 120:60:60 NPK kg.ha^{-1}, 150:75:75NPK kg.ha^{-1} Variety HPR 35 recorded significantly higher plant height, branches, total dry matter, seed and straw yield over rest of the varieties. Application of 120:60:60 NPK kg.ha^{-1} was at par with 150:75:75 NPK kg.ha^{-1} and recorded significantly higher number of pods per plant, 100 seed weight and seed yield over application of 90:45:45 NPK kg.ha^{-1}

Dahmardeh *et al.* (2010) assessed the effect of plant density (D) and cultivars (V) on some growth characters of faba bean. Plant density at three levels (12.5, 16.7 and 20 plant m^{-2}) and cultivars at four levels (Aljazayeri, Barekat, Shami and var. 3514) were used as experimental treatments. The obtained results showed that some characters were markedly affected by plant density, except plant height, height of the lowest pods of soil surface, 100 seeds weight, number of pods per plant and number of seed per pod. Increasing plant density from 12.5 to 20 plant m^{-2} significantly increased economical yield and biological yield. As such, the cultivars had a significant effect on economical and biological yields. Aljazaeri cultivar surpassed all other cultivars in terms of biological and economical yields, whereas the interaction effect of 'D x V' was significant for both biological and economical yields. Increasing plant spacing increased the number of pods per plant, but a decrease in the number of seed/pods consequently gave the highest seed yield. However, cultivars had no significant effect on yield and other investigated characters. Thus, the use of Algazayeri cultivar at the highest plant density produced the best seed and biological yield in this condition.

Ramana *et at*. (2011) reported that Application of 75 per cent RDF + VAM@ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} significantly increased the plant height (cm), number of branches per plant, leaf area (cm^2) and dry weight (g) of plant in the variety Arka Suvidha (V_2) followed by selection 9 and Arka Komal. The

number of clusters per plant, number of pods per plant, number of pods per cluster, number of seeds per pod, 100 seed weight (g), pod length, pod yield per plant (g) and pod yield per hectare (t/ha), crude protein and fibre content (%) was significantly increased by the application of 75 per cent RDF + VAM @ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} in Arka Suvidha (V_2) variety.

Chadha et el. (2013) evaluated different varieties of garden pea were conducted consecutively for two years (2011-12 and 2012-13) at Model Organic Farm, CSKHPKV, Palampur for identifying suitable varieties responsive to organic farming system. Fifty five genotypes of pea including three check varieties viz., Palam Priya, Palam Smool and Punjab-89 were evaluated in Augmented block design with five replicates of check varieties. The seeds were sown at 45 × 10 cm spacing during second week of November consecutively for two years. Out of 55 genotypes/varieties of garden pea screened during Rabi 2011-12 & 2012-13 for higher productivity under organic farming conditions, EC538008 was recorded the highest yielding (108.58 q/ha) and was statistically at par with Kukumseri-6(101.61 q/ha), IC 267732(101.07 q/ha), DPPM-74 (92.84 q/ha) and DPP-54(91.96 q/ha). It was also statistically at par with two standard checks viz., Palam Priya (85.24) and Punjab-89 (91.12 q/ha)

Sharma *et al.* (2013) conducted a field experiment to study the optimum sowing time and varieties has seed… The 12 treatment combinations comprised of four dates of sowing at weekly interval starting from 1st June in main plot and three varieties namely Luxmi, SVM-1 and Kentucky Wonder in sub-plots. The early sowing on 1st June significantly resulted in higher seed yield with 23, 77 and 85% more increase over 8th June, 15th June and 22nd June, respectively in pooled years. Among the varieties, ‘SVM-1’ significantly out performed ‘Luxmi’ and ‘Kentucky Wonder’ for seed yield with a respective increase of 63 and 44% in pooled years and also performed better for pods/plant and straw yield. Interaction effects of sowing dates and varieties on the performance revealed that the seed yield of all the varieties, in general, decreased with each delay in sowing with more drastic reduction after 15th June. The cultivar ‘SVM-1’ performed significantly better on all four dates of sowings over ‘Luxmi’ and ‘Kentucky

Wonder' for number of pods/plant, seed yield and straw yield over the years. Hence, it can be concluded that early sowing on 1st June and the cultivar 'SVM-1' was the most ideal combination to obtain higher seed yield of pole French bean under sub-humid temperate environment.

Kasinath (2015) determined the differential response of French bean varieties to phosphorous fertilization under acidic alfisols at Bangalore conditions suggested that French bean varieties have unique genetic properties that regulate their response to different phosphorous levels. Results have showed differences in pod yield amongst six genotypes of French bean. The highest pod yield was observed in Arka Komal. A positive relationship was observed between the available phosphorus and phosphorus use efficiency (PUE). Soil available phosphorous was reduced in 100% NPK applied plots without farm yard manure (FYM). On the other hand the available phosphorous increased in the plots, which were applied with 50% NPK along with FYM. Pod yield did not show any relationship with biomass production and PUE. The higher rate of PE and AE was positively correlated with higher yielding varieties.

Muthuramu *et al*. (2015) evaluated the yield performance and market preference of three French bean varieties namely Arka Komal, Arka Suvidha and Arka Anoop in Virudhunagar district. The green pod yield was more or less similar in Arka Anoop (185q/ha) and Arka Suvidha (180q/ha) due to their yield contributing traits namely number of primary branches per plant , 4.06 and 4.18 ; number of green pods per plant, 16.60 and 19.08 and green pod length ,15.32 and 17.00 in Arka Anoop and Arka Suvidha, respectively as compared to farmer's choice of variety. Even though the green pod yield was recorded more in Arka Anoop, the net return and B : C ratio was higher in Arka Suvidha due to higher market price. Farmers realized that both Arka Anoop and Arka Suvidha were better choice of varieties in terms of yield and market price.

Santhi *et al*. (2015) evaluated ten accessions of traditional french beans - types yield and quality Observations as indicated in the pooled means of four years from 2010 to 2013, among the bush bean types, accession number FBB-7

(Aruvath avarai) has recorded highest pod yield of 712.73 g/plant and pod weight of 15. 80g/ pod. The highest genotypic coefficient of variation was observed for number of leaves, pod weight and yield. High heritability values were observed in plant height, number of branches, number of leaves, days for flowering and pod development, pod length, pod diameter, pod weight and yield. The expected genetic advance expressed as percentage of mean was relatively high for the characters *viz.,* plant height, branch, number of leaves, days for flowering, days for pod development, pod length, pod diameter, pod weight and yield.

Nazrul and Shaheb (2016) examined the suitable varieties (genotypes) of French bean for maximize the seed yield of the farmers. Eight bush bean genotypes were tested of which 3 were developed by BARI (var. BARI Jharsheem-1, BARI Jharsheem-2, BARI Jharsheem-3), five local accessions: Local-1(black), Local-2 (white colour with chocolate spot at hylum), Local-3 (coffee colour), Local-4 (coffee colour with few chocolate spots) and Local-5 (black with chocolate colour spots). The seed yields were varied significantly among the genotypes. All the local French bean lines performed better and produced higher seed yields compared to BARI developed varieties. The maximum seed yields 2.66, 3.48 and 2.05 t ha-1 was produced by Local-4 and Local-5 at Jalalpur, Zakigonj and Moulvibazer, respectively. So, Local-4 and Local-5 variety as the most promising one due their relatively good plant vigor and high seed yield potentiality.

Sharma *et al.* (2016) observed high genotypic and phenotypic coefficients of variations for seed yield/plant followed by moderate for majority of the traits. A positive correlation was observed for seed yield/plant with fresh pod yield/plant, pods/plant, 100-seed weight, average pod weight, plant height, pod length, biological yield/plant and branches/plant. On the basis of correlation and path coefficient analysis, selection on the basis of pods/plant, fresh pod yield/plant, 100-seed weight, plant height and branches/plant would be a paying proposition for evolving high yielding genotypes. A significant association between seed yield/plant and fresh pod yield is of significance to explore the

possibilities to develop dual purpose French bean variety (ies) both for vegetable and dry bean.

Jamil Uddin *et at.* (2017) determined the optimum sowing date for selected French bean varieties under Bangladesh condition. The experiment consisted of two factors namely; (i) variety *viz.* BARI Jhar Sheem-1, BARI Jhar Sheem-2 and BARI Jhar Sheem-3, and (ii) sowing date *viz.* 5 November, 20 November and 5 December Variety and sowing date showed significant effect on most of the plant characters *viz.* plant height, leaf area plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, weight of 1000 seeds, seed yield and Stover yield. The highest seed yield (0.66 t ha^{-1}) was obtained from BARI Jhar Sheem-3 and the lowest (0.46 t ha^{-1}) was obtained from both BARI Jhar Sheem-1 and BARI Jhar Sheem-2. The highest seed yield (0.65 t ha^{-1}) was obtained from 20 November sowing and the lowest one (0.36 t ha^{-1}) was obtained from 5 November sowing. The interaction between variety and sowing date had significant influence on the yield.

Das *et al.* (2018) conducted an experiment to study the performance of eight bush type french bean (*Phaseolus vulgaris* L.) varieties (Shagun, Victoria, Falguni, Falkon Improved, Arka Komal, special Jhati Beans, Nandini and Basuki) regarding growth, fresh pod yield and quality in this region with and without *Rhizobium* inoculation. In case of inoculation treatment, irrespective of varietal differences, seeds were treated with *Rhizobium phaseoli* 10g/kg of seed. Common fertilizer dose of 80:40:40 N:P_2O_5:K_2O kg/ha was applied in each plot. The experimental results revealed that *Rhizobium* inoculation increased the yield and quality parameters *viz,* protein %, vitamin-A content and ascorbic acid content in the fresh pods of the French bean varieties. However, flowering and harvesting were recorded earlier in without *Rhizobium* inoculation treatment due to less accumulation of nitrogen content inside the plant bodies. Under *Rhizobium* inoculation Special Jhati Beans recorded the highest pod yield (23.05 tonnes/ha) followed by Victoria (22.43 tonnes/ha) and Arka Komal (21.95 tonnes/ha). Regarding without inoculation treatment Arka Komal recorded the higher yield (20.05 tonnes/ha) followed by Special Jhhati Beans (20.01tonnes/ha)

and Nandini (18.76 tonnes/ha).Considering the benefit: cost ratio, french bean varieties ‘Special Jhhati Beans’ and ‘Victoria’ might be selected for the terai region of West Bengal with a benefit :cost ratio of 2.94 and 2.83 respectively.

Muthal *et at*. (2018) studied correlation and performance evaluation of french bean (*Phaseolus vulgaris* L.) varieties were studied for growth, yield and yield attributing characters. The experiment involves twelve varieties. Among the varieties studied, Arka Anoop was better with respect to growth, yield and yield attributing characters followed by Best of All and Arka Komal. Correlation studies are important to know the interrelationship among the characters. This also gives fair idea of contribution of different characters towards yield. Correlation studies revealed that pod yield per hectare exhibited significant positive correlation with primary branches per plant, clusters per plant, pods per cluster, pods per plant, yield per plant, root nodules and dry matter content in pod at genotypic and phenotypic level while plant height, weight of ten pods, pod length and pod width showed positive association with pod yield per hectare. Days to first flowering and days to fifty per cent flowering showed negative correlation with the pod yield per hectare.

Meena *et at.* (2018) worked on bio-fertilizers on yield and quality traits of french bean (*Phaseolus vulgaris* L.) cultivars. Different bio-fertilizers were taken Azotobactor, Phosphate solubilizing bacteria, Rhizobium, Azospirillum and Vesicular-arbuscular mycorrhizae (VAM). Three varieties PDR-14(Uday), EC-400445 and IPR-98-3-1 were used for investigation. The results revealed that the application of V1B3 (PDR-14 (Uday) + Rhizobium) significantly days to first flowering, and days to 50 per cent flowering, number of pods/ plant, number of grains/ pod, green pod length(cm), green pod width(cm), green pod breadth (cm), single green pod weight, green pod yield/plant (g), green pod yield/plot (kg), green pod yield (q/ha), seed weight (g), moisture (%), total sugars (%), protein (%) and also the same trend in PDR-14 (V_1) except green pod length in IPR-98-3-1. It is found that PDR-14 (Uday) performed better in respect of yield and quality traits in French bean under Lucknow condition.

Rahman *et al*. (2018) assessed the effect of phosphorus levels on the growth, yield attributes and yield of French bean (*Phaseolus vulgaris* L.) varieties. The experiment was conducted maintaining randomized complete block design consisting three French bean varieties, viz. V_1 - BARI Jhar Sheem-1, V_2 - BARI Jhar Sheem-2 and V_3 – Nick and four levels of phosphorus viz. P_0, P_{20}, P_{40} and P_{60} kg phosphorus ha^{-1}, respectively replicated thrice. Varieties showed significant results on growth and yield attributes except number of branches $plant^{-1}$ but phosphorus exhibited significant results of all growth and yield attributes except number of seeds pod^{-1}. Varieties combined with phosphorus given significant results of all the parameters. Highest pod yield (22.70 t ha^{-1}) was obtained from BARI Jhar Sheem-2 while lowest (16.64 t ha^{-1}) from BARI Jhar Sheem-1. Highest dose of phosphorus @ 60 kg ha^{-1} gave highest pod yield (22.12 t ha^{-1}), where as lowest (18.82 t ha^{-1}) was obtained in control. Apparently, the highest value of pod yield (24.40 t ha^{-1}) was found from the combination of BARI Jhar Sheem-2 with 60 kg ha^{-1} phosphorus and lowest (15.23 t ha^{-1}) from the combination of BARI Jhar Sheem-1 with control treatment.

Thakur *et at.* (2018) conducted as experiment to study the effect of Rhizobi-um and Phosphorus Solublizing Bacteria (PSB) on the horticultural and yield traits in french bean var. Contender. Six treatments comprising seed treatments (with and without *Rhizobium*), seed treatment (with and without PSB) along with the combination of 60 % dose of recommended quantity of Calcium Ammonium Nitrate and 75 % dose of recommended quantity of Single Super Phosphate and organic matter were evaluated The results revealed that T5 treatment, i.e. Rhizobium+ PSB+ Organic matter resulted in more number of pods per plant (20), pod length (18 cm) and pod yield/ha (140 q/ha) .

Zeliang *et al*. (2018) evaluated high yielding French bean varieties for optimization of crop productivity and nutritional security of poor tribal community. Results revealed that yield attributes *i.e.* pod weight; pod length and pods/plant were markedly influenced by French bean cultivars among themselves. The highest pod weight (11.3 g), pod length (11.3 cm) and pods/plant (24.1) were recorded with Arka Anoop, which were significantly higher as compared to Arka

Komal and Arka Suvidha. However, the lowest values of these attributes were associated with local cultivar. Similarly, significantly higher green pod yield was recorded with Arka Anoop (6.5 t/ha) followed by Arka Komal (6.1 t/ha) and Arka Suvidha (5.8 t/ha).

2.3 Combined effect of irrigation regime and varieties

Anwar *et al*. (2003) studied the effect of irrigation and sowing date on crop yield of chickpea. The study also aimed at quantifying the yield potential of the crop under varying irrigation regimes and sowing dates. Green area duration (GAD), intercepted radiation (Fi), radiation use efficiency (U) and total intercepted PAR were significantly ($P<0.001$) increased by irrigation. Total dry matter (TDM) yield was more strongly correlated (R_2=0.69–0.83) with GAD than seed yield (R_2=0.60–0.69). Accumulation of TDM was highly related to intercepted PAR. Fully irrigated November-sown crops had a final U of 1.46 g DM/MJ PAR. The unirrigated crop had a U of only 0.92 g DM/MJ PAR. The Utended to decrease with delayed sowing. Averaged over the 2 years, irrigation increased seed yield by 74–124% and trends were similar for TDM yield. Seed yield was doubled in November-sown chickpeas (4.6 t/ha) and cv. Sanford produced 14 and 16%more seed than cvs Dwelley and B-90 respectively. Full irrigation from emergence to physiological maturity always gave the highest seed yield (>4.7 t/ha), and there was no indication of a critical period of sensitivity to water stress. Based on results collected in the first growing season a simple model relating seed yield to radiation interception, U and HI was made. Results from the second growing season were then used as a simple verification to test the accuracy of predictions. The results suggest that these varieties have the potential to yield more than 4.5 t/ha of seed in Canterbury.

Khah (2004) studied the effect of the duration of irrigation on the quality and yield of seed of two cultivars of dwarf green bean (Larma, and Montano, *Phaseolus vulgaris* L.) was studied during fall and spring in Greece. Seeds were sown on 11 Sept. 2000 fall crop and 23 Feb. 2001 (spring crop) in peat compost and when the plant had two expanded leaves (11 and 20 days after sowing,

respectively), they were transplanted ot the soil of an unheated, plastic- covered greenhouse. The following irrigation treatments were applied: 1) irrigation for the entire duration (control), 2) irrigation until the first pods were dry ,3) irrigation until 50 % of the pods had filled, and 4) irrigation till flowering. Fall cultivation was not suitable for seed production due to low yield and reduced seed quality.By contrast, the spring crop had a higher yield, seed size and good germination. Stopping irrigation of the spring crop at the drying of the first pods aachieved an = 20% saving in water without significantly affecting seed yield or quality. Earlier discontinuation of irrigation to achieve greater savings of water caused a reduction in yield, but did not affect seed quality.

El-Noemani *et al.* (2010) investigated the effect of different irrigation systems (surface drip, subsurface drip, gated pipes and furrow irrigation) and water regimes (100%, 80% and 60% Eto) on vegetative growth, productivity and WUE of snap bean (*Phaseolus vulgaris* L.) varieties Paulista and Bronco. Results showed that surface drip (SD) and/ or subsurface drip (SSD) systems exhibited the highest values of vegetative growth (plant height, No. branches, No. leaves, No. pods, leaves area and dry weight of stem, leaves, pods and total plant); pods yield (kg/fed) and WUE followed by gated pipes (GP) meanwhile furrow irrigation (FI) recorded the lowest values in the same concern. Increasing irrigation treatment up to 100% ETo exhibited the highest values of vegetative growth. However, the highest values of pods yield/fed. and WUE were achieved by 80% Eto treatment. Paulista variety exhibited its superiority in growth parameters. However, Bronco variety surpassed Paulista one in pods yield /fed and WUE. It could be concluded that under the conditions of the experiment or any other similar conditions, Bronco bean variety is recommended in cultivation (for export or local marketing) with irrigation at 80% Eto, corresponding to1556 m^3/ fed. / season, using surface or subsurface drip irrigation systems due to its superiority in green pods yield/ fed. with higher efficiency in using water (WUE) and finally higher net profits/ fed.

Tayel and sabrceh (2011) studied the effect of skipping two irrigations at different growth stages and phosphorous levels on yield, water and phosphorous

use efficiency of faba bean varieties (Giza Blanka, GB and Giza 461,G461). Phosphorous was applied at the rate of P_1, P_2, and P_3 (20, 15 and 10 Kg P_2O_5 fed $^{-1}$) during seedbed preparation. Plants were subjected to the following irrigation regimes : IR_1= continuous irrigation, concerning the other 3 irrigation regimes IR_2, IR_3 and IR_4, two irrigations were skipped at floral initiation, flowering and podding stages, respectively. Under deficit irrigation in arid and semi – arid regions using the treatments (GB; IR_2; P_1) and (GB.; IR_4; P_1) saved 11.4 and 4.7 of irrigation water and in the same time achieved comparable yield. Seed yield, straw yield, water use efficiency and phosphorous use efficiency ranged 1.578-2.770, 2.61- 5.29 ton fed. $^{-1}$, 1.219- 2.135 Kg seed m^{-3} of water and 113.1-197.85 Kg seeds / Kg P2O5 according to faba bean variety, irrigation regime and phosphorous applied.

Mekonnen (2012) reported that Green area duration (GAD), intercepted radiation (Fi), radiation use efficiency (U) and total intercepted PAR were significantly ($P<0.001$) increased by irrigation. Total dry matter (TDM) yield was more strongly correlated (R_2=0.69–0.83) with GAD than seed yield (R_2=0.60–0.69). Accumulation of TDM was highly related to intercepted PAR. Fully irrigated November-sown crops had a final U of 1.46 g DM/MJ PAR. The unirrigated crop had a U of only 0.92 g DM/MJ PAR. The U tended to decrease with delayed sowing. Averaged over the 2 years, irrigation increased seed yield by 74–124% and trends were similar for TDM yield. Seed yield was doubled in November-sown chickpeas (4.6 t/ha) and cv. Sanford produced 14 and 16% more seed than cvs Dwelley and B-90 respectively. Full irrigation from emergence to physiological maturity always gave the highest seed yield (>4.7 t/ha), and there was no indication of a critical period of sensitivity to water stress. Based on results collected in the first growing season a simple model relating seed yield to radiation interception, U and HI was made. Results from the second growing season were then used as a simple verification to test the accuracy of predictions. The results suggest that these varieties have the potential to yield more than 4.5 t/ha of seed in Canterbury.

Tripathi *et al.* (2012) observed the effect of varieties, irrigation and nitrogen management on the fibre yield of sunhemp. The results showed no significant varietal difference on fibre yield but irrigation at 18 days interval and nitrogen @ 20 kg ha^{-1} was found lo increase the fibre yield significantly.

Ghanbari *et al*.(2013) determined the changes of nitrogen contents in the leaves and seeds of common bean (*Phaseolus vulgaris* L.) genotypes under contrasting moisture regimes, Two levels of irrigation (irrigation after 55-60 and 100-110 mm evaporation from class A pan, respectively) and eight genotypes including white beans (WA4502-1 and WA4531-17), red beans (Akhtar, D81083 and AND1007) and Chitti beans (KS21486, MCD4011 and COS16) were studied in the main- and sub-plots, respectively. Leaf nitrogen (N) and proline contents were measured at two growth stages (pre-flowering and pod filling period). Grain yield, seed N and seed protein contents were measured at harvest. The results indicated that white beans had lower leaf N and seed protein contents than red and Chitti beans under both irrigation regimes. Under drought conditions, AND1007 and COS16 showed markedly higher levels of accumulation of leaf N and proline. Seed protein was higher in Chitti beans. Water deficit reduced the leaf N by 19% and 28% at two growth stages and grain yield by 39.8%. By contrast, proline content of all genotypes was increased by 105%. Seed N and protein contents had the lowest reductions under drought, while increasing N and proline contents in the leaves increased grain yield under this condition. Besides, lower values of seed N and protein is associated with higher yields of genotypes. Totally, based on the grain yield, red beans were more drought-susceptible than white and Chitti groups.

Fooladivanda *et al*. (2014) evaluated the impact of water stress and levels of potassium on yield and yield components of two varieties of mung bean (*Vigna radiata)* (promising lines VC6172 and Indian). Water stress in three levels: irrigation at 120 (no stress), 180 (moderate stress) and 240 (severe stress) mm evaporation from pan, were allocated to the main plots and potassium fertilizer at three levels (0, 90,180 kg /ha) and two varieties of mung bean (promising line VC6172 and Indian) were allotted to the sub-plots. Results showed that water stress and potassium fertilizer significantly affect all traits. The highest grain yield (2093 kg /ha) was obtained from no stress treatment in the case of 180 kg /ha potassium. Total dry matter, number of pods and grain yield, were significantly

different between the two varieties. The interaction between fertilizer and variety, on dry matter and grain yield and the interaction between irrigation and variety, on dry matter were significant. We conclude that use of potassium fertilizer can reduce the adverse effects of water stress.

Megawer *et al*. (2017) studied the effect of irrigation and sowing date on plant characteristics, chemical and yield traits of five faba bean cultivars irrigation intervals (I) was considered as the main plot in the three intervals (irrigation every 20, 30 and 40 days). Three sowing dates (22^{nd} Oct., $7^{th}$and 22^{nd}Nov.) were arranged in the sub plot. The sub-sub plots were varieties (Nubaria1, Nubaria2, Giza3 improved, Sakha1 and Sakha2). Results indicated that the effect of irrigation every 20 days (I_1) surpassed the others two where it produced higher values of plant height (87.34cm), seed yield (1.81ton/feddan) and carbohydrate % (46.73%).The early sowing date (22^{nd} October) produced the highest values of all yield attributes and carbohydrate percentage with the exception of harvest index and protein percentage in combined analysis. Giza3 improved achieved the superiority only on plant height trait, while Nubaria2 achieved the superiority on number of pods/plant and height to first pod. While, Nubaria1 variety presented the first class in number of branches, pods and seeds weight/plant, 100-seed yield, seed and straw yield and carbohydrate % The highest values of pods and seeds weight/plant were 57.04 and 45.32 gm, as well as 100-seed weight (gm) and seed yield (ton/fed.) were 118.37 (gm) and 2.04 (ton/fed.) respectively, were obtained by irrigation every 30 days with early sowing with Nubaria1 variety.

CHAPTER-III

MATERIAL AND METHODS

Chapter- III

MATERIAL AND METHODS

This chapter comprises of the methods employed and material used during the course of investigation entitled “Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (*Phaseolus vulgaris* L.)” The details of the material and methods are being given under the following heads:

3.1 Experimental site

The experiment was conducted during Rabi season of 2018-19 at Bahadari farm, College of Horticulture, Mandsaur, Madhya Pradesh. Mandsaur is lies in western part of Madhya Pradesh, between latitude of $23^{o}45'$ to $24^{o}13'$ North, longitude of 74^{o} 44’ to $75^{o}18'$ East and at an altitude of 435.20 m above mean sea level. This region is under Malwa Plateau, the 9^{th} agro climatic zone of the state. The topography of the experimental field is plain.

3.2 Climatic conditions

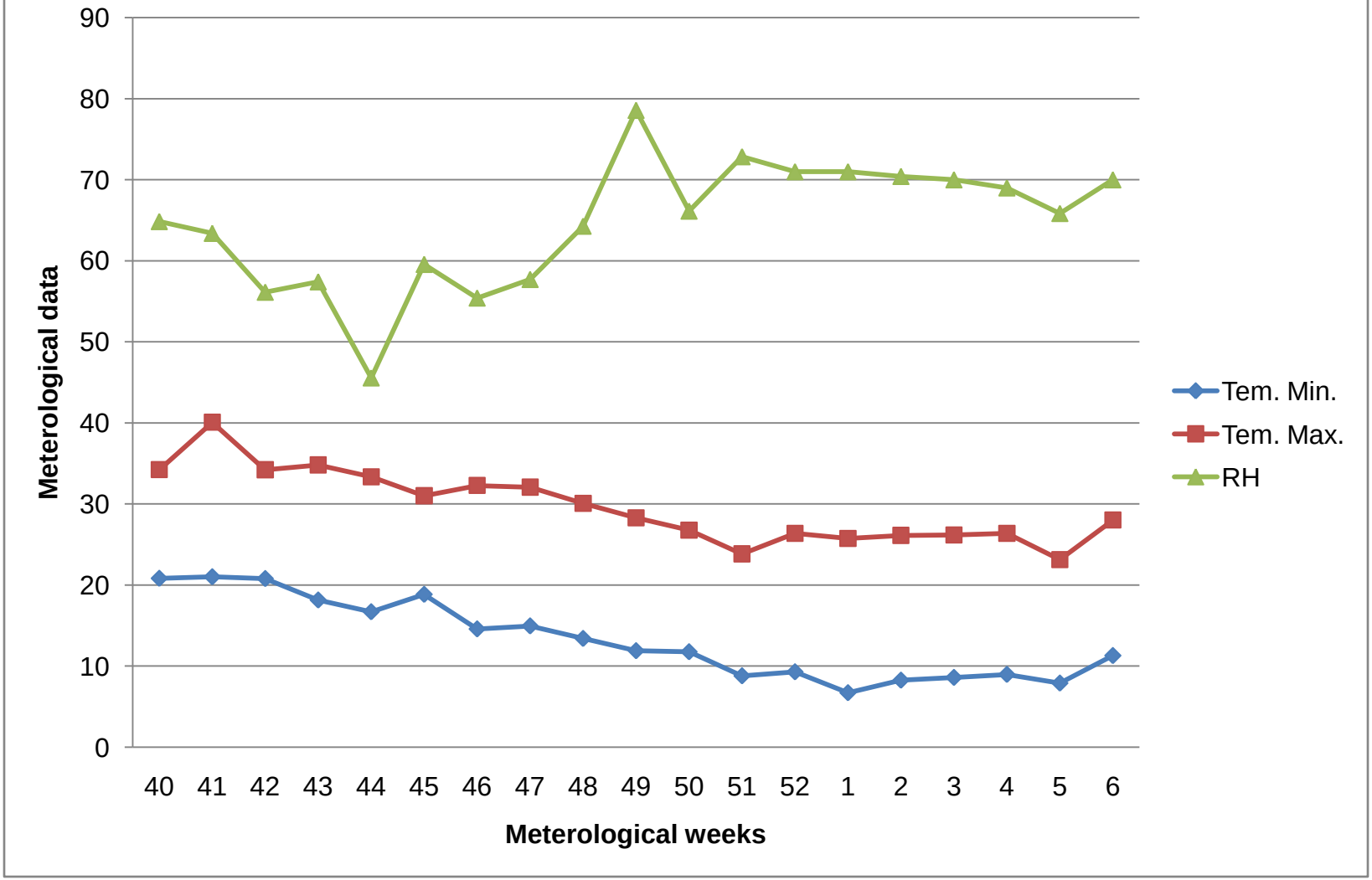
Mandsaur has sub-tropical and semi-arid climatic conditions with a temperature range of 5^{0}C minimum and 4^{0}C maximum in winter and summer respectively. In this region maximum rainfall is received during mid June to September. The average annual rainfall is 544.05 mm. South - west monsoon is responsible for major part of annual precipitation. Meteorological data recorded during the period of investigation are presented in Table 1 and depicted through Figure 1.

Table 1. Meteorological data during the period of investigation from Oct 2018 to Feb 2019

Standard week	Duration date	Temperature		R.H. %
		Min. (^{0})	Max.(^{0}c)	
40	01 – 07 Oct	20.85	34.24	64.85
41	08 – 14 Oct	21.04	40.08	63.4
42	15– 21 Oct	20.82	34.22	56.14
43	22 – 28 Oct	18.17	34.81	57.42
44	29 – 04 Nov	16.72	33.35	45.57
45	05 – 11 Nov	18.87	31.02	59.57
46	12 – 18 Nov	14.60	32.28	55.42
47	19 – 25 Nov	14.97	32.07	57.71
48	26 – 02 Dec	13.42	30.08	64.28
49	03 – 09 Dec	11.91	28.30	78.57
50	10 – 16 Dec	11.78	26.77	66.14
51	17 – 23 Dec	8.81	23.85	72.85
52	24 – 31 Dec	9.30	26.37	71.00
1	01 – 07 Jan	6.72	25.74	71.00
2	08 – 14 Jan	8.27	26.12	70.42
3	15 – 21 Jan	8.61	26.17	70.00
4	22 – 28 Jan	8.98	26.37	69.00
5	29 – 04 Feb	7.91	23.14	65.85
6	05 – 11 Feb	11.31	28.02	70.00

Source: Meteorological observatory of the College of Horticulture, Mandsaur (M.P.).

Fig. 1: Meterological data during the period of investigation from Oct. 2018 – Feb 2019



3.3 Soil of the experimental field

The soil of the experimental field was light alluvial soil having sandy loam texture with uniform topography and bulk density 1.20 g/cm^3. Before sowing, soil samples of the field up to a depth of 15 cm were taken randomly from the field, with the help of soil auger. All the soil samples were mixed to prepare a composite sample, which was then air dried sieved through 2 mm sieve and finally used for mechanical and chemical analysis. The results are presented in Table 3.2

Table 2: Physical and chemical composition of the soil

S. No.	Composition			Method
	Physical	**Content**	**Category**	
1.	Sand %	55	-	Bouyoucos Hydrometer
2.	Slit %	35	-	Bouyoucos Hydrometer
3.	Clay %	10	-	Bouyoucos Hydrometer
4.	Bulk density (g/ cm3)	1.20	-	
5.	Field capacity %	20.8	-	
6.	Soil pH	7.32	Neutral	Glass electrode pH meter
7.	Electrical conductivity (dSm-1)	0.32	Normal	By conductivity bridge at 250C
8.	Available nitrogen (kg/ha)	190	Low	Rapid titration method (Walkley and Black ,1934)
9.	Available phosphorus (kg/ha)	11.5	Medium	Olesen's extraction method (Olesen et al., 1954)
10.	Available potassium (kg/ha)	356.4	High	Flame photometer (Ghosh et al.,1981)

Table 3: Previous year crop history of the experimental field

Year	Season	
	Kharif	**Rabi**
2016 -17	Soyabean	Opium
2017 -18	Ashwagandha	Gram
2018-19	Soyabean	-

3.4 Experimental details:

3.4.1 Experimental design and layout

Name of crop	:	French bean (*Phaseolus vulgaris* L.)
Season	:	*Rabi* season, 2018-19
Design	:	Split Plot Design
Number of replications	:	3
Number of treatments		
(a) Irrigation levels	:	3
(b) Varieties	:	5
Treatment combination	:	15
Total numbers of plots	:	45
Spacing	:	Row to Row - 45 cm Plant to Plant - 15 cm
Gross plot size	:	3.37 m^2 (2.25 x 1.5 m)
Net plot area	:	1.62 m^2 (1.35 x 1.2 m)
Total experimental area	:	243.37 m^2
Net experimental area	:	151.65 m^2
Date of sowing	:	02/10/2018
Date of harvesting	:	2 to 12 February, 2019

3.4.2 Treatment details:

Irrigation was given on the basis of CPE (Cumulative Pan Evaporation) which was recorded from Pan Evaporimeter installed near to experimental field. Quantity of water in each irrigation (IW) was 50 mm. Daily CPE values have been given in Appendix-XIII

1. Irrigation levels (I):

I_1 – IW/CPE = 0.60
I_2 – IW/CPE = 0.80
I_3 – IW/CPE = 1.00

2. Varieties (V):

V_1 - Arka Komal
V_2 - Arka Arjun
V_3 - Arka Sharath
V_4 - Kashi Rajhans
V_5 - Kashi Sampann

Table 4: Notations for different treatment combinations used in experiment

Treatment	Treatment detail	Symbol
T_1	IW/CPE = 0.60 + Arka Komal	I_1V_1
T_2	IW/CPE = 0.60 + Arka Arjun	I_1V_2
T_3	IW/CPE = 0.60 + Arka Sharath	I_1V_3
T_4	IW/CPE = 0.60 + Kashi Rajhans	I_1V_4
T_5	IW/CPE = 0.60 + Kashi Sampann	I_1V_5
T_6	IW/CPE = 0.80 + Arka Komal	I_2V_1
T_7	IW/CPE = 0.80 + Arka Arjun	I_2V_2
T_8	IW/CPE = 0.80 + Arka Sharath	I_2V_3
T_9	IW/CPE = 0.80 + Kashi Rajhans	I_2V_4
T_{10}	IW/CPE = 0.80 + Kashi Sampann	I_2V_5
T_{11}	IW/CPE = 1.00 + Arka Komal	I_3V_1
T_{12}	IW/CPE = 1.00 + Arka Arjun	I_3V_2
T_{13}	IW/CPE = 1.00 + Arka Sharath	I_3V_3
T_{14}	IW/CPE = 1.00 + Kashi Rajhans	I_3V_4
T_{15}	IW/CPE = 1.00 + Kashi Sampann	I_3V_5

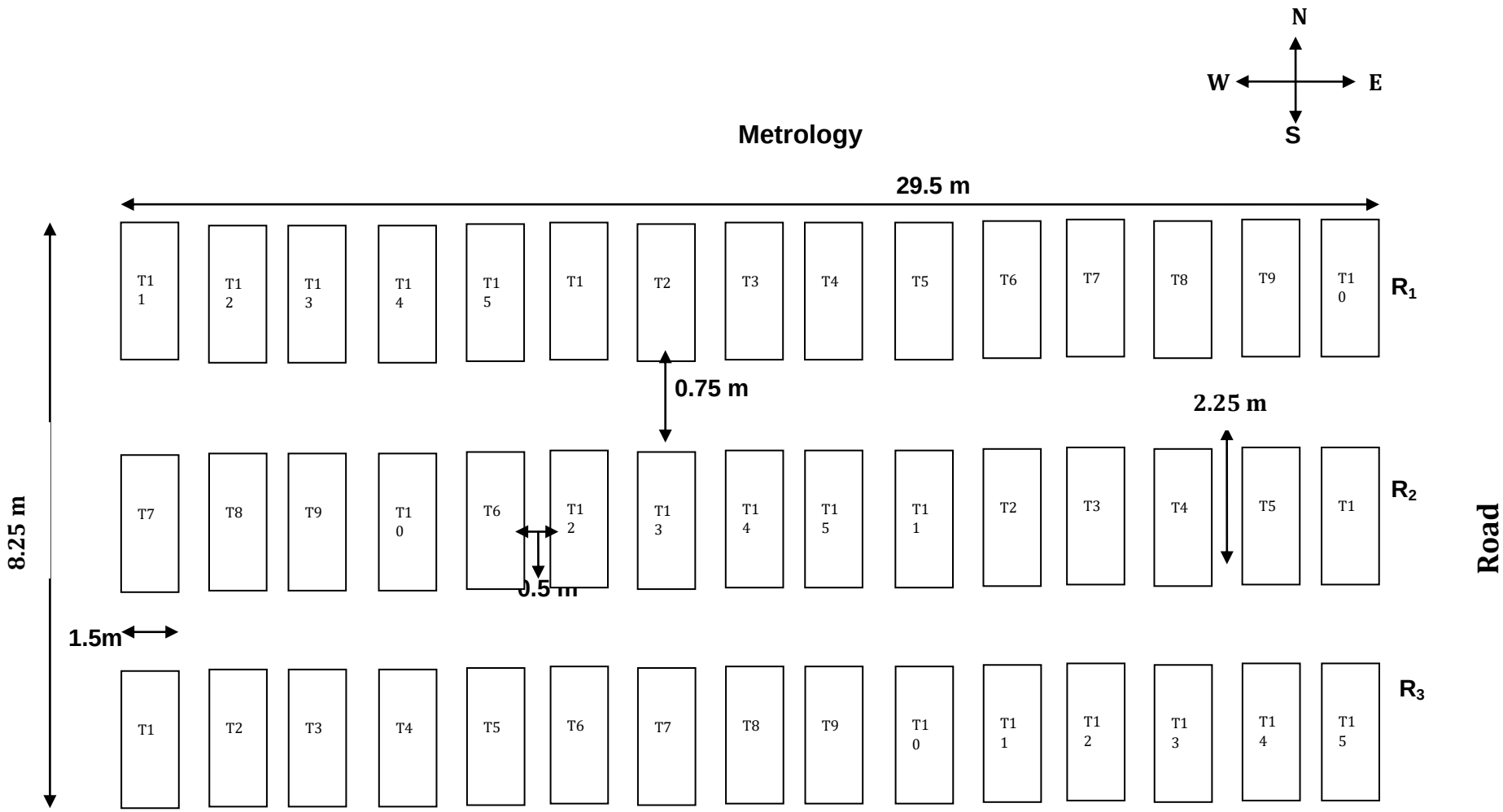


Fig. 2 Layout of experimental field of french bean

3.5 Agronomic Operations

3.5.1 Field preparation

Field was ploughed with tractor drawn mould board plough. Thereafter cross harrowing was done followed by planking to make the field leveled.

3.5.2 Nutrient Management

Nitrogen, phosphorus and potassium were provided through urea. According to the treatment, the full quantity of phosphorus, potash and half of nitrogen was applied as basal at the time of sowing. While the remaining ½ quantity of nitrogen was applied 30 days after sowing.

3.5.3 Seed

Pure, healthy and good quality seed of French bean varieties viz., Arka Komal, Arka Arjun, Arka Sharath, Kashi Rajhans and Kashi Sampann was obtained from department of Vegetable Science, College of Horticulture, Mandsaur.

3.5.5 Gap filling and re-sowing

The gap filling and re-sowing was carried out after 10 days of sowing.

3.5.6 Weeding

It was done manually at 25, 35 and 45 days after sowing.

3.5.7 Irrigation

For the establishment of the crop, first light irrigation was done just after sowing then subsequent irrigation was done as per the requirement of crop.

Table 5. Date of irrigation under different treatments:

S. No.	I_1	I_2	I_3
1.	18/10/2018	15/10/2018	12/10/2018
2.	05/11/2018	27/10/2018	22/10/2018
3.	02/12/2018	11/11/2018	01/11/2018
4.	19/01/2019	03/12/2018	15/11/2018
5.	-	08/01/2019	03/12/2018
6.	-	09/02/2019	30/12/2018
7.	-	-	28/01/2019

3.5.8 Plant protection measures

Seeds were treated with Mancozeb 75% WP before sowing. Use of Thimet 10G (10-15 kg/ha) and Imidacloprid 35% EC (0.3ml/litre) was done to control the insect pests. Prophylactic spray of Mancozeb 75% WP (2g/litre) and Carbendazim (1g/litre) was done to check the diseases.

3.5.9 Harvesting

Crop was harvested when plants turned its colour from green to creamy. At harvesting stage whole plant dried up. The colour of pod was also changed from green to creamy. The crop was harvested 1st, 2 February and on 12nd February 2019.

3.6 Observations recorded

Five plants were randomly selected from each treatment and each replication passing up the border plants. The tagging was done after 25 DAS. Observation data were recorded on the tagged plants for the following attributes

3.6.1 Growth attributes

(i) Plant height (cm)

The height was measured in five-tagged plant in each treatment from ground level to the tip of fully opened leaves of main stem with the help of meter scale at 30, 45 and 60 days after sowing.

(ii) Number of leaves per plant:

The number of leaves was counted in five tagged plant in each experimental plot at 30, 45 and 60 days after sowing. Thereafter, average number of leaves per plant was calculated at each stage.

(iii) Number of branch per plant:

The number of branches in five tagged plants of each experimental plot was counted at 30, 45 and 60 days after sowing and their averages were worked out.

(iv) Fresh weight of shoot of plant (g)

The fresh weight of root of five randomly selected plants from each plot was determined at 30, 45 and 60 days after sowing and at harvesting stage.

(v) Dry weight of shoot of plant (g)

After taking fresh weight, plants were put in hot air oven at 65±5^{O}C temperatures for drying till constant weight. Final weight was noted and average was worked out at each stage.

(vi) Fresh weight of root of plant (g)

The fresh weight of root of five randomly selected plants from each plot was determined at 30, 45 and 60 days after sowing and at harvesting stage.

(vii) Dry weight of root of plant (g)

After taking fresh weight, plants were put in hot air oven at 65±5^{O}C temperature for drying till constant weight. Final weight was noted and average was worked out at each stage

3.6.2 Phenological attributes

(i) Number of node of 1st flower appearance

The node number was counted in tagged plants from the base of stem to the nodes number at which first flower appeared and mean value worked out.

(ii) Days taken to1st flower appearance

The data when first open flower appeared on each tagged plant was noted and days to first flower from the date of sowing calculated and average values worked out.

(iii) Days taken to 50 percent flowering

The days taken from date of sowing to the date when 50 percent plant show flowering at least one flower open were counted and average values worked out.

3.6.3 Yield Parameters and Yield

(i) Number of pods per plant

The numbers of pods were counted in 10 randomly selected plants and average was worked out for each treatment.

(ii) Number of seed per pod

Ten pods were picked randomly from the harvested pods and their seeds were counted and average values were worked out.

(iii) Pod length (cm)

Length of 10 randomly selected pods was measured after each harvesting and mean was calculated for each treatment.

(iv) Shelling percentage

Shelling percentage was calculated with taking total weight of pods in a plot and total weight of seed in a plot by following formula:

$$\text{Shelling percentage} = \frac{\text{Weight of seed}}{\text{Total weight of pod}} \times 100$$

(v) Seed yield per plant (g)

The seed obtained from all the pods of each observational plant was weighed and mean of seed yield per plant was calculated.

(vi) Seed yield per hectare (q/ha)

Seed yield per net plot was converted into quintal per hectare by multiplying it with 10000\3.78.

(vii) Harvest index (%)

The harvest index was obtained by the economic yield (seed yield) from total biological yield and expressed as percentage

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.4 Quality Parameters

(i) Crude protein content (%)

Crude protein content in french bean seed was determined as given below:

Procedure for crude protein content in french bean seed

(i) Weigh 0.5 g of plant sample into 500 ml dry (corning/borosil) conical flask.

(ii) Add 25 ml of H_2SO_4 and add 1g Digestion mixture and digested the content on kel plus-kes-12 digestion.

(iii) The digested samples were distilled off on kel-plus automatic nitrogen analyzer.

(iv) Distill the sample by adding concentrate NaOH and steam for 10 minutes.

(v) Absorb the ammonia gas in 20 ml standard boric acid added with drope of methyl red indicator.

(vi) The protein content of the sample was calculated by multiplying percent nitrogen content in sample with the factor 6.25 (A.O.A.C., 1960).

(ii) Weight of 100 seeds (g)

100 seeds were taken randomly from each plot and their weight was worked out on digital balance. The average of seed weight was noted as test weight or weight of 100 seeds.

(iii) Germination (%)

Seed germination was tested at 20^{o}C for 8 days with three replicates of 100 seeds for each treatment (ISTA, 1985). The seeds were evenly distributed in 15 cm Petri dishes on papers, moistened with 7 ml of water daily. Each Petri dish was covered with its lid and placed in BOD Incubator for germination. Number of seeds germinated was recorded in each treatment and percentage was calculated by the formulae given below:

$$\text{Germination (\%)} = \frac{\text{No. of germinated seeds}}{\text{Total no. of seed}}$$

3.6.5 Water utilization parameters

(i) Total water use (cm) - (n-1) x depth of water/ irrigation + effective rainfall (cm) + moisture depletion after last irrigation in terms of depth of water.

Table 6: Total water used (cm)

Treatment	No. of irrigation (n-1)	Depth of irrigation (cm)	Water provided through irrigation	Effective rain fall (cm)	Moisture depletion depth of water (cm)	Total water used (cm)
T_1	4	5.0	20.0	-	3.50	23.50
T_2	4	5.0	20.0	-	3.48	23.48
T_3	4	5.0	20.0	-	3.46	23.46
T_4	4	5.0	20.0	-	3.44	23.44
T_5	4	5.0	20.0	-	3.42	23.42
T_6	6	5.0	30.0	-	3.39	31.39
T_7	6	5.0	30.0	-	3.37	31.37
T_8	6	5.0	30.0	-	3.35	31.35
T_9	6	5.0	30.0	-	3.33	31.33
T_{10}	6	5.0	30.0	-	3.31	31.31
T_{11}	7	5.0	35.0	-	3.19	38.19
T_{12}	7	5.0	35.0	-	3.17	38.17
T_{13}	7	5.0	35.0	-	3.15	38.15
T_{14}	7	5.0	35.0	-	3.13	38.13
T_{15}	7	5.0	35.0	-	3.11	38.11

(ii) Water use efficiency (q/ha-cm)

Water utilization by the crop is generally described in terms of water use efficiency (q/ha-cm). Water use efficiency was calculated by dividing total pod yield with water used by the crop.

$$\text{Water use efficiency} = \frac{Y}{\text{Water use by the crop (cm)}}$$

Where,

n = number of irrigation

Y = seed yield (q/ha)

3.7 Statistical analysis:

The data obtained on various observations for each treatment were subject to "Analysis of variance" as recommended by Panse and Sukhatme (1984). The skeleton of ANOVA as per design is as follows:

Table 7: Skeleton of analysis of variance

The significance of the treatment difference was judged by using critical difference (C.D.), which was calculated by using formula given by Panse and Sukhatme (1984).

Source of variation	Degree of freedom	Sum of square	Mean sum of square	"F" Value Calculated	"F" tab at5%
Replication	2	RSS	RMS	RMS/E(A)MS	4.10
Irrigation levels (I)	2	(I) SS	(I)MS	IMS/E(A)MS	3.33
Error A	4	(A) SS	(A) MS	(A)MS/E(A)MS	
Varieties (V)	4	(V) SS	(V) MS	(V)MS/E(B)MS	3.40
Interaction (I x V)	8	(IXV)SS	IXV MS	IVMS/E(B)MS	2.25
Error B	24	(B)SS	E(B)MS	(B)SS/E(B)MS	
Total	44				

3.7.1 Standard errors and critical difference (C.D.)

(i) Difference between two main plot treatment (irrigation) means

$$= \sqrt{\frac{\text{Error variance (MSE1)}}{r \times v}}$$

C.D. for irrigations

$$= \sqrt{\frac{2 \times \text{Error variance (MSE1)}}{r \times v}} \times t\ 5\% \text{ at level of Error 1 df}$$

(ii) Standard error for two sub-plot treatment (Varieties) means

$$= \sqrt{\frac{\text{Error variance (EMS2)}}{r \times i}}$$

C.D. for varieties

$$= \sqrt{\frac{2 \times \text{Error variance (EMS2)}}{r \times i}} \times t\ 5\% \text{ at level of Error 2 df}$$

(iii) Difference between two sub-plot treatments (Varieties) means at the level of main plot treatment (irrigation)

$$= \sqrt{\frac{2 \times \text{Error variance (EMS2)}}{r}}$$

C.D. for Varieties at the level of irrigations:

$$= \sqrt{\frac{2 \times \text{Error variance (EMS2)}}{R}} \times t\ 5\ \% \text{ at level of Error 2 df}$$

(iv) Difference between two main plot treatment (irrigation) means at the same or different levels of sub-plot treatments (Varieties).

$$= \sqrt{\frac{2 \times (f-1)\, MSE2 + MSE1}{r \times v}}$$

C.D. for irrigation at the same or different levels of the Varieties

$$= \sqrt{\frac{2 \times (f-1)\, MSE2 + MSE1}{r \times v}} \times t$$

$$t = \frac{ta MSE1 + tb\,(v-1)\, MSE2}{MSE1 + (v-1)\, MSE2}$$

Where, ta = t value at Error1 d.f. at a given level of significance

tb = t value at Error2 d.f. at a given level of significance

r = Number of replications I = Number of Irrigation levels

v= Number of Varieties t ='t' Table value at error degree of freedom



Plate 1:- A panoramic view of experimental field of french bean

CHAPTER-IV

RESULTS

Chapter- IV

RESULTS

This chapter deals with the findings on various growth, yield and quality parameters under the investigation entitled **"**Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (*Phaseolus vulgaris* L.)". Data were subjected to statistical analysis in order to find out the significance of different treatments by using the analysis of variance technique for split plot design. The experimental findings are interpreted along with the corresponding Tables and Figures as follows:

4.1 Growth Parameters

Observations on plant height, number of leaves per plant, number of branch per plant was recorded at 30, 45 and 60 DAS. Fresh weight of shoot, dry weight of shoot, fresh weight of root and dry weight of root were recorded at harvest stage, are presented as follows:

4.1.1 Plant height (cm)

Plant height was recorded at 30, 45 and 60 DAS (days after sowing). The results presented in Table 8 and Fig. 3 showed significant influence on plant height with irrigation levels and varieties of french bean.

It was observed that the plant height of french bean was significantly affected by irrigation levels. Maximum plant height 19.13, 27.38 and 38.55 cm was found with irrigation level I_3 (IW/CPE=1.00) which was followed by 17.74, 26.20, 34.74 cm under irrigation level I_2 (IW/CPE= 0.80) at 30, 45 and 60 DAS, respectively. Minimum plant height of 15.43, 25.22 and 31.85 cm was observed under the irrigation level I_1 (IW/CPE=0.60) at 30, 45 and 60 days after sowing, respectively.

Maximum plant height recorded at 30, 45 and 60 DAS was 20.97, 29.60 and 38.65 cm, respectively with the variety V_1 (Arka Komal) which was superior over the other varieties, while minimum plant height of 13.77, 23.31 and 31.02 cm was recorded under V_4 (Kashi Rajhans) at 30, 45 and 60 DAS, respectively.

Table 8: Effect of irrigation levels, varieties and their interactions on plant height (cm) in French bean

Treatment	Plant height (cm)		
	30 DAS	45 DAS	60 DAS
Irrigation level (I)			
I_1	15.43	25.22	31.85
I_2	17.74	26.20	34.74
I_3	19.13	27.38	38.55
S.Em ±	0.31	0.40	1.07
CD at 5%	1.23	1.57	4.19
Varieties (V)			
V_1	20.97	29.60	38.65
V_2	15.67	24.37	33.80
V_3	19.39	27.70	36.62
V_4	13.77	23.31	31.20
V_5	17.37	26.35	34.97
S.Em ±	0.45	0.64	0.98
CD at 5%	1.32	1.86	2.86
Interaction (I × V)			
I_1V_1	19.46	28.94	35.27
I_1V_2	13.41	24.09	30.24
I_1V_3	17.81	26.58	33.14
I_1V_4	11.09	20.88	27.74
I_1V_5	15.40	25.57	32.88
I_2V_1	21.36	29.72	37.80
I_2V_2	15.78	24.78	33.34
I_2V_3	19.66	27.86	36.53
I_2V_4	14.15	21.92	30.55
I_2V_5	17.72	26.73	35.49
I_3V_1	22.10	30.15	42.88
I_3V_2	17.83	24.23	37.83
I_3V_3	20.71	28.65	40.20
I_3V_4	16.06	27.13	35.30
I_3V_5	18.97	26.75	36.53
S.Em ±	0.78	1.10	1.69
CD at 5%	NS	NS	NS

Fig. 3a: Effect of irrigation levels on plant height (cm) in frrench bean

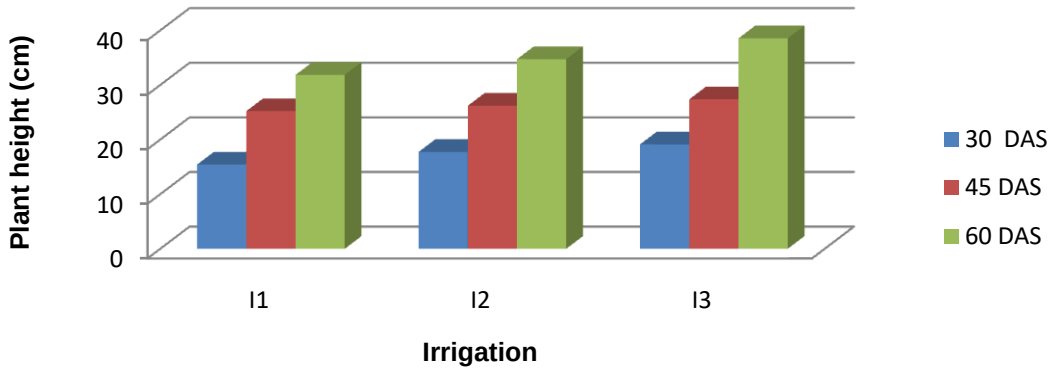


Fig. 3b: Effect of varieties on plant height (cm) in french bean

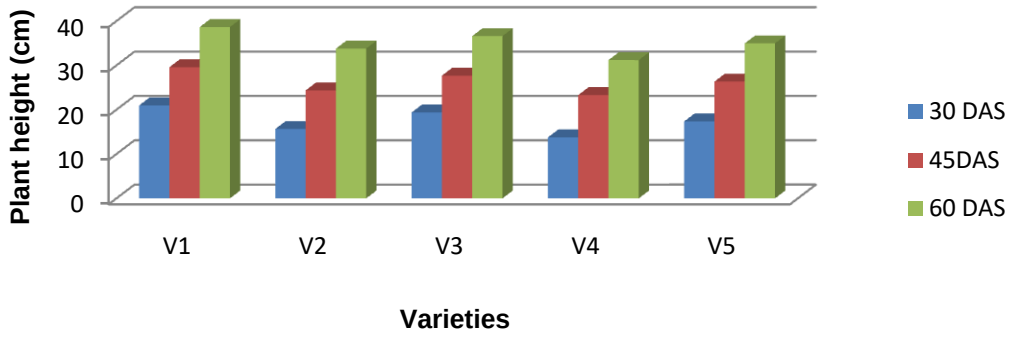
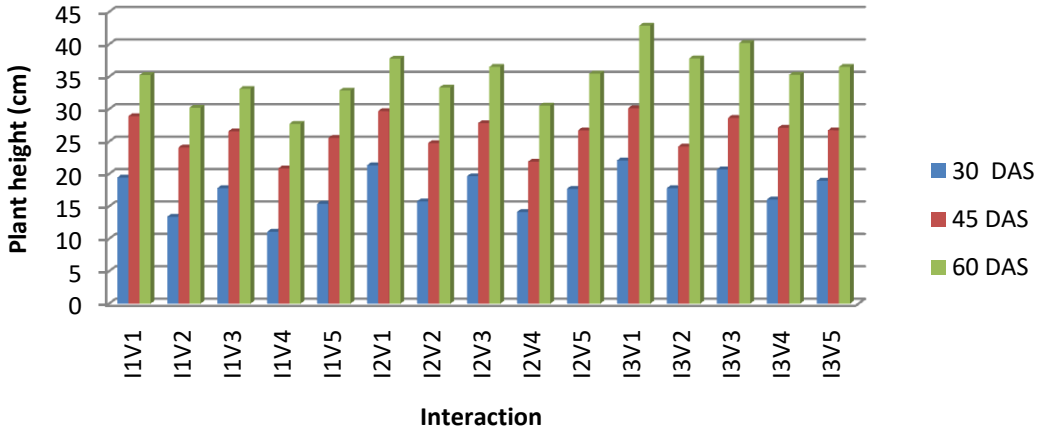


Fig. 3c: Interaction effect of irrigation levels and varieties on plant height (cm) in french bean



Combined effect of irrigation levels and varieties had showed non-significant influence on plant height at all the stages of growth under the study In French bean**.**

4.1.2 Number of leaves per plant

Number of leaves per plant was recorded at 30, 45 and 60 days after sowing. The data presented in Table 9 and Fig.4 revealed significant effect of irrigation levels and varieties on number of leaves per plant at all the growth stages.

Irrigation levels had exerted significant effect on number of leaves per plant at all the growth stages. Among the irrigation levels, I_3 (IW/CPE=1.00) recorded maximum number of leaves i.e. 15.29, 28.88 and 38.66 per plant at 30, 45 and 60 DAS, respectively. It was followed by irrigation level I_2 (IW/CPE=0.80). Minimum number of leaves i.e. 9.84, 22.93 and 30.79 per plant were noted under irrigation level I_1 (IW/CPE=0.60) at 30, 45 and 60 days after sowing, respectively.

Varieties exerted significant effect on number of leaves per plant. Maximum number of leaves i.e. 14.35, 29.29 and 37.17 per plant were recorded under variety V_1 (Arka Komal), which was followed by V_3 (Arka Sharath) with the 12.70, 26.89 and 36.38 leaves per plant at 30, 45 and 60 DAS, respectively. Minimum number of leaves was recorded in case of variety V_4 (Kashi Rajhans) which were 10.30, 23.96 and 32.30 per plant at 30, 45 and 60 DAS, respectively.

Combined effect of irrigation levels and varieties had non-significant effect on number of leaves per plant. However, numerically maximum number of leaves i.e. 16.44, 32.78 and 41.62 per plant was recorded under the treatment combination I_3V_1 (IW/CPE=1.00+ Arka Komal) at 30, 45 and 60 DAS, respectively, whereas the minimum number of leaves i.e. 6.81, 20.67 and 29.24 per plant was recorded with the treatment combination I_1V_4 (IW/CPE=0.60+Kashi Rajhans) at 30, 45 and 60 DAS, respectively.

Table 9: Effect of Irrigation levels, Varieties and their interaction on number of leaves per plant in french bean

Treatment	Number of leaves per plant		
	30 DAS	45 DAS	60 DAS
Irrigation levels (I)			
I_1	9.84	22.93	30.79
I_2	11.59	26.39	34.58
I_3	15.29	28.88	38.66
S.Em ±	0.43	0.67	0.37
CD at 5%	1.70	2.65	1.45
Varieties (V)			
V_1	14.35	29.29	37.17
V_2	11.14	23.73	33.43
V_3	12.70	26.89	36.38
V_4	10.30	23.96	32.30
V_5	12.72	26.47	34.11
S.Em ±	0.35	0.78	1.09
CD at 5%	1.02	2.29	3.19
Interaction (I × V)			
I_1V_1	12.57	26.49	33.28
I_1V_2	8.74	20.07	28.32
I_1V_3	10.71	24.33	32.40
I_1V_4	6.81	20.67	29.24
I_1V_5	10.38	23.07	30.73
I_2V_1	14.05	28.58	36.60
I_2V_2	10.80	24.00	35.09
I_2V_3	11.51	27.20	35.01
I_2V_4	10.27	24.85	32.58
I_2V_5	11.33	27.33	33.61
I_3V_1	16.44	32.78	41.62
I_3V_2	13.87	27.14	36.89
I_3V_3	15.88	29.14	41.73
I_3V_4	13.81	26.36	35.07
I_3V_5	16.44	29.00	38.00
S.Em ±	0.61	1.36	1.89
CD at 5%	NS	NS	NS

Fig. 4a: Effect of irrigation levels on number of leaves per plant in french bean

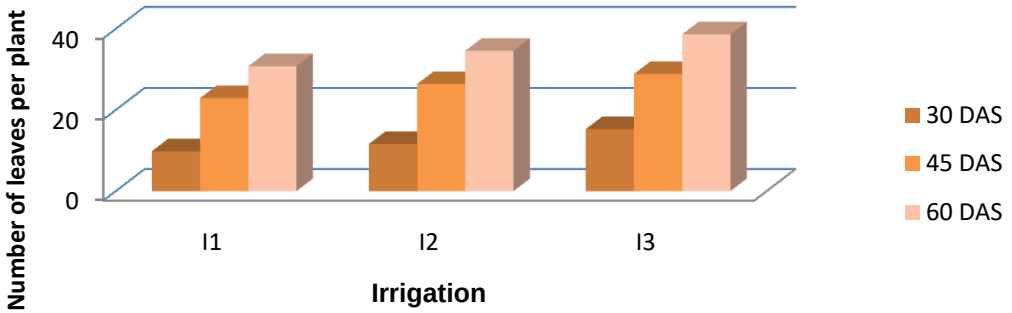


Fig. 4b: Effect of varieties on number of leaves per plant in french bean

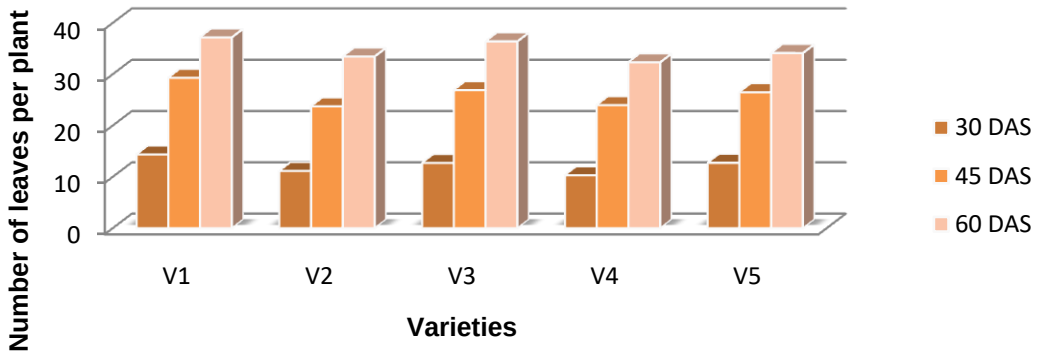
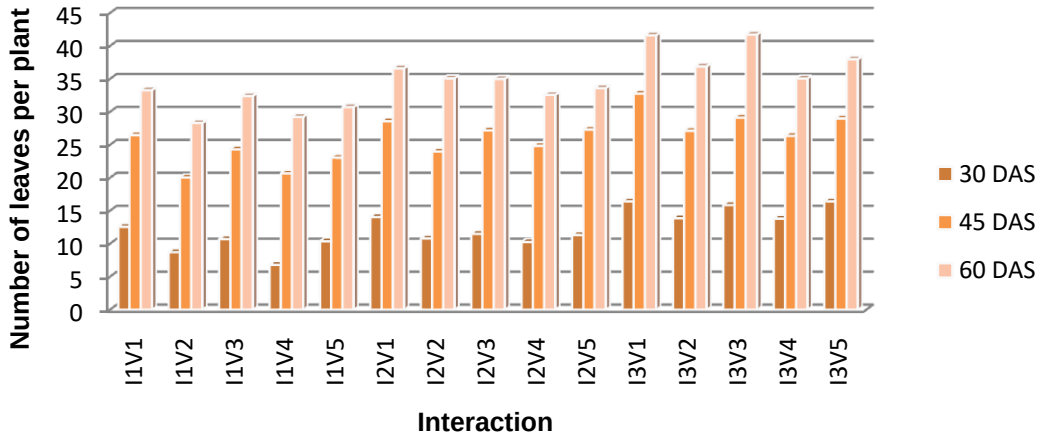


Fig. 4c: Interaction of irrigation levels and varieties on number of leaves per plant in french bean



4.1.3 Number of branches per plant

Number of branches per plant was counted at 30, 45 and 60 DAS. Perusal of data presented in Table 10 and Fig. 5 revealed significant influence of irrigation levels and varieties on number of branches per plant at 30, 45 and 60 DAS in french bean. Interaction effect of irrigation levels and varieties had non significant influence on number of branches per plant in French bean.

Irrigation levels had exerted significant effect on number of branches per plant at all the growth stages. The maximum number of branches 4.39, 8.15 and 8.86 per plant were recorded under irrigation level I_3 (IW/CPE=1.00) at 30, 45 and 60 DAS, respectively. It was followed by irrigation level I_2 (IW/CPE=0.80). Minimum number of branches per plant i.e. 2.66, 6.24 and 7.16 were noted under irrigation level I_1 (IW/CPE=0.60) at 30, 45 and 60 days after sowing, respectively.

Varieties had significant effect on number of branches per plant. Maximum number of branches per plant i.e. 4.92, 8.92 and 9.89 were recorded under variety V_1 (Arka Komal), which was followed by variety V_3 (Arka Sharath) with the 3.59, 7.94 and 8.99 branches per plant at 30, 45 and 60 DAS, respectively. Minimum number of branches was recorded in case of variety V_4 (Kashi Rajhans) i.e. 3.00, 5.72 and 6.52 per plant at 30, 45 and 60 DAS, respectively.

Combined effect of irrigation levels and varieties showed non- significant effect on number of branches at all the growth stage in french bean. However, numerically maximum number of branches i.e. 3.76, 8.45 and 8.33 per plant was recorded under the treatment combination I_3V_1 (IW/CPE=1.00+ Arka Komal) at 30, 45 and 60 DAS, respectively, whereas the minimum number of branches i.e. 3.97, 7.53 and 7.26 per plant was recorded with the treatment combination I_1V_4 (IW/CPE=0.60+Kashi Rajhans) at 30, 45 and 60 DAS, respectively.

Table 10: Effect of Irrigation levels, Varieties and their interaction on number of branches per plant in french bean

Treatment	Number of branch per plant (cm)		
	30 DAS	45 DAS	60 DAS
Irrigation levels (I)			
I_1	2.66	6.24	7.16
I_2	3.64	7.32	8.30
I_3	4.39	8.15	8.86
S.Em ±	0.15	0.10	0.23
CD at 5%	0.61	0.38	0.88
Varieties (V)			
V_1	4.92	8.92	9.89
V_2	2.85	6.35	7.47
V_3	3.59	7.94	8.99
V_4	3.00	5.72	6.52
V_5	3.46	7.27	7.65
S.Em ±	0.14	0.25	0.25
CD at 5%	0.40	0.72	0.73
Interaction (I × V)			
I_1V_1	3.76	8.45	8.33
I_1V_2	2.20	5.15	6.67
I_1V_3	2.75	6.88	7.82
I_1V_4	2.01	4.44	5.97
I_1V_5	2.57	6.29	7.03
I_2V_1	4.91	9.28	10.13
I_2V_2	3.32	6.52	7.51
I_2V_3	3.51	8.27	9.10
I_2V_4	3.02	5.18	6.32
I_2V_5	3.43	7.37	8.42
I_3V_1	6.08	9.04	11.22
I_3V_2	3.02	7.38	8.23
I_3V_3	4.50	8.67	10.05
I_3V_4	3.97	7.53	7.26
I_3V_5	4.37	8.16	7.52
S.Em ±	0.24	0.43	0.43
CD at 5%	NS	NS	NS

Fig. 5a: Effect of irrigation levels on number of branches per plant in french bean

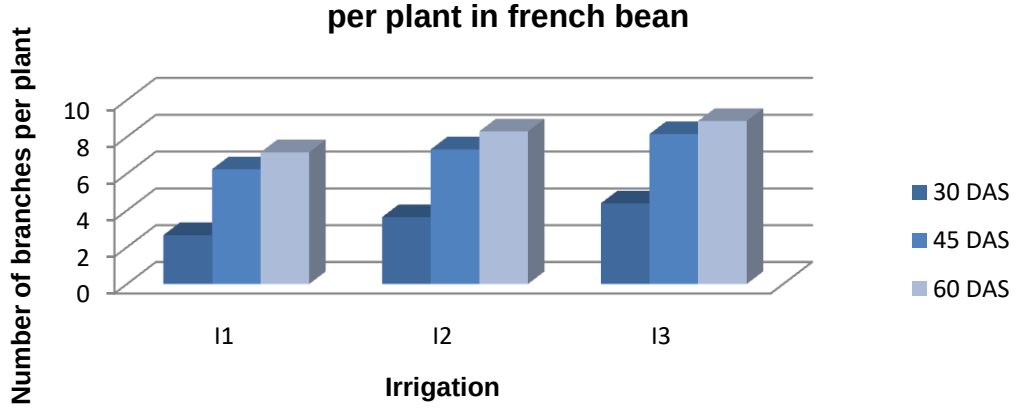


Fig. 5b: Effect of varieties on number of branches per plant in french bean

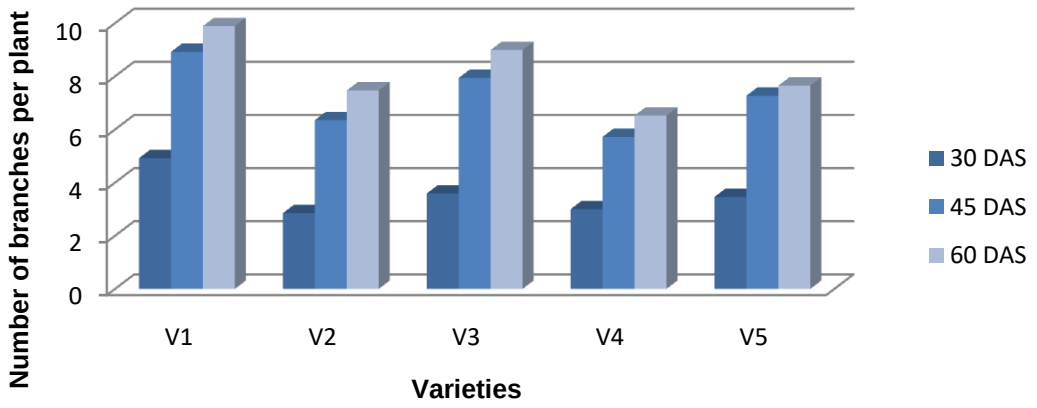
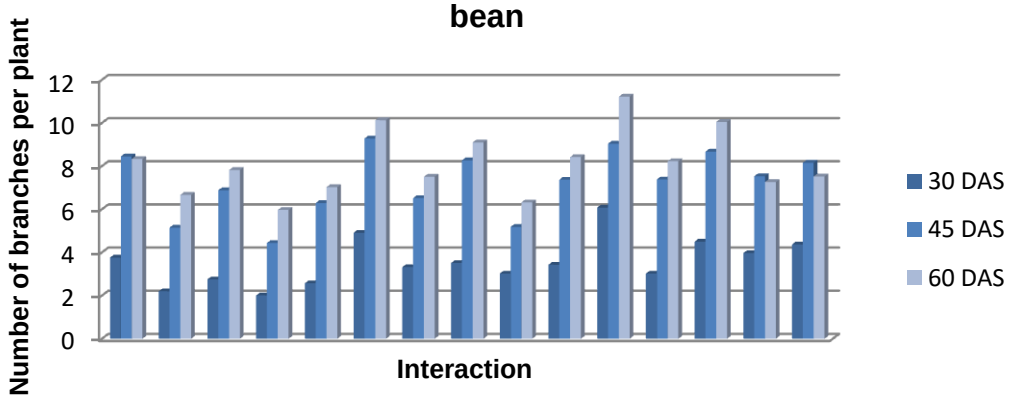


Fig. 5c: Interaction effect of irrigation levels and varieties on number of branches per plant in french bean



4.1.4 Fresh weight of shoot (g)

The results on fresh weight of shoot (g) as influenced with irrigation levels and varieties are presented in Table 11 and Fig. 6 Fresh weight of shoot revealed significant effect of irrigation levels and varieties.

The irrigation level I_3 (IW/CPE=1.00) recorded maximum fresh weight of shoot (38.56 g). It was followed by I_2 (IW/CPE=0.80). Application of I_1 (IW/CPE= 0.60) irrigation level found minimum fresh weight of shoot (35.08 g) in french bean.

Maximum fresh weight of shoot (39.21 g) was found with variety V_1 (Arka Komal), It was followed by V_3 > V_5 >V_2 in descending order. Minimum fresh weight of shoot (34.58 g) was observed with variety V_4 (Kashi Rajhans).

Combined effect of irrigation regimes and varieties imposed non-significant effect on fresh weight of shoot in french bean.

Table 11: Effect of irrigation level, varieties and their interaction on fresh weight shoot (g) in french bean

Irrigation levels (I)	Fresh weight of shoot (g)					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	37.44	35.47	36.70	31.39	34.40	**35.08**
I_2	38.46	36.65	38.53	34.78	37.49	**37.18**
I_3	41.73	35.94	39.56	37.56	38.03	**38.56**
MEAN	**39.21**	**36.02**	**38.26**	**34.54**	**36.64**	

	I	V	I×V
S. Em ±	0.66	1.00	1.74
CD at 5%	2.58	2.93	NS

Fig. 6a: Effect of irrigation levels on fresh weight of shoot (g) in french bean

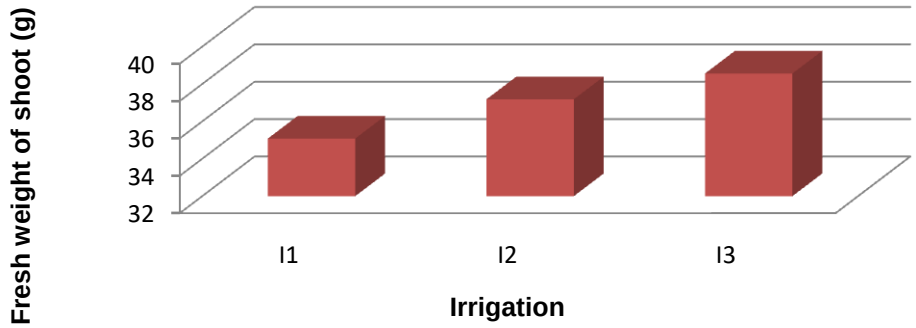


Fig. 6b: Effect of varieties on fresh weight of shoot (g) in french bean

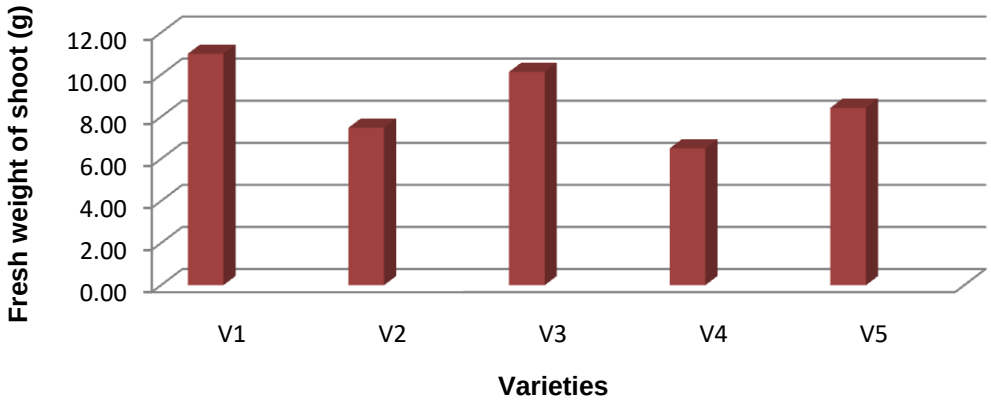
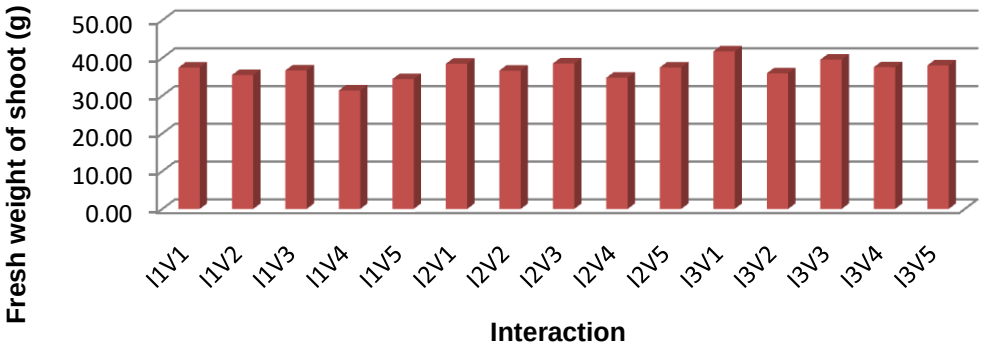


Fig. 6c: Interaction effect of irrigation levels and varieties on fresh weight of shoot (g) in french bean



4.1.5 Dry weight of shoot (g)

The data regarding dry weight of shoot presented in Table 12 and depicted in Fig. 7 revealed significant influence of irrigation levels and varieties.

The irrigation levels had imposed significant influence on dry weight of shoot (g). The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered significantly maximum dry weight of shoot (10.87 g), which was followed by irrigation level I_2 (IW/CPE=0.80). Whereas minimum dry weight of shoot (6.45 g) was recorded with the irrigation level I_1 (IW/CPE=0.60).

Varieties showed significant effect on dry weight of shoot. Among the varieties, V_1 (Arka Komal) registered maximum dry weight of shoot (11.00 g) which was followed by Varieties $V_3>V_5>V_2$ in descending order. Minimum dry weight of shoot (6.50 g) was recorded in case of variety V_4 (Kashi Rajhans).

Interactions effect of irrigation levels and varieties had non-significant influence on dry weight of shoot.

Table 12: Effect of irrigation levels, varieties and their interaction on dry weight shoot (g) of french bean

Irrigation levels (I)	Dry weight shoot (g)					
	Varieties(V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	8.77	4.94	7.52	4.92	6.10	**6.45**
I_2	11.17	8.02	10.87	5.97	8.01	**8.81**
I_3	13.05	9.49	12.03	8.62	11.17	**10.87**
MEAN	**11.00**	**7.48**	**10.14**	**6.50**	**8.43**	

	I	V	I×V
S. Em ±	0.19	0.25	0.44
CD at 5%	0.74	0.74	NS

Fig. 7a: Effect of irrigation levels on dry weight of shoot (g) in french bean

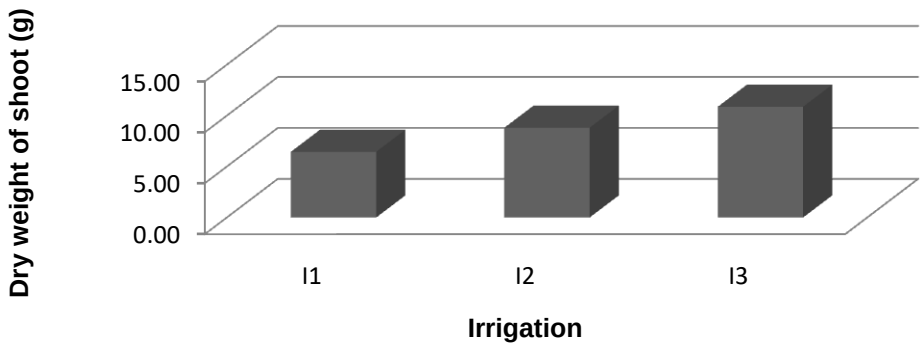


Fig. 7b: Effect of varieties on dry weight of shoot (g) in french bean

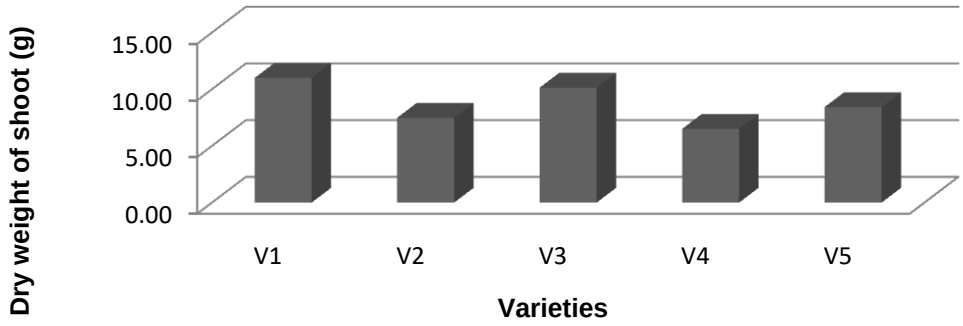
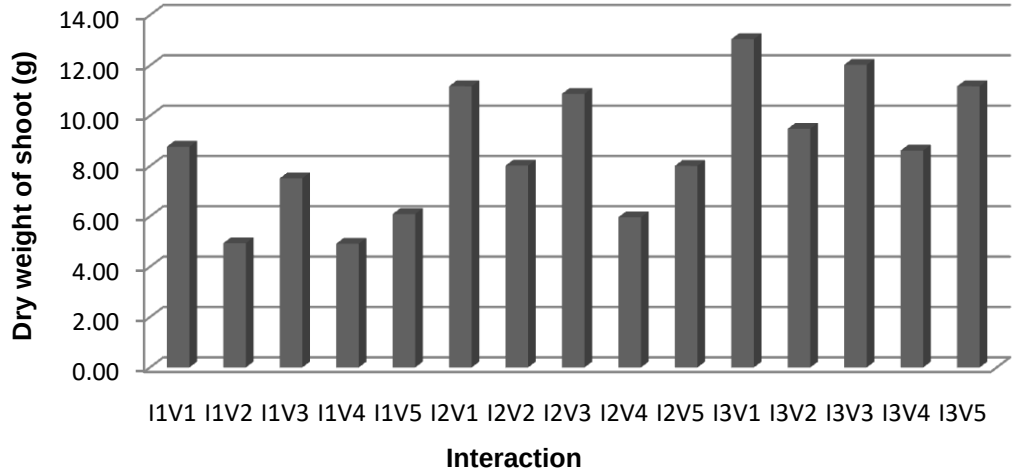


Fig. 7c: Interaction effect of irrigation levels and varieties on dry weight of shoot (g) in french fean



4.1.6 Fresh weight of root (g)

The results on fresh weight of root (g) as influenced with irrigation levels and varieties are presented in Table 13 and Fig. 8 Fresh weight of plant revealed significant effect of irrigation levels and varieties. Combined effect of irrigation levels and varieties showed non significant effect on fresh weight of root.

Among the irrigation treatments, irrigation level I_3 (IW/CPE=1.00) recorded maximum fresh weight of root (6.47 g) followed by irrigation level I_2 (IW/CPE=0.80). Application of I_1 (IW/CPE=0.60) irrigation level found minimum fresh weight of root (4.53 g) in french bean.

Maximum fresh weight of root (7.23 g) was found with variety V_1 (Arka Komal). It was followed by 16.73 g in V_3 (Arka Sharath). Minimum fresh weight of root (15.44 g) was recorded with variety V_4 (Kashi Rajhans).

. Combined effect of irrigation regimes and varieties imposed non-significant effect on fresh weight of root (g).

Table 13: Effect of irrigation levels, variety and their interaction on fresh weigh of root per plant (g) at last harvesting stage.

Irrigation levels (I)	Fresh weight of root per plant (g)					MEAN
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	
I_1	5.54	3.22	5.34	2.58	4.94	**4.53**
I_2	7.52	5.53	5.38	4.85	6.30	**5.92**
I_3	7.64	5.90	6.77	5.72	6.31	**6.47**
MEAN	**7.23**	**4.88**	**5.83**	**4.39**	**5.85**	

	I	V	I×V
S. Em ±	0.22	0.23	0.40
CD at 5%	0.86	0.67	NS

Fig. 8a: Effect of irrigation levels on fresh weight of root (g) in french bean

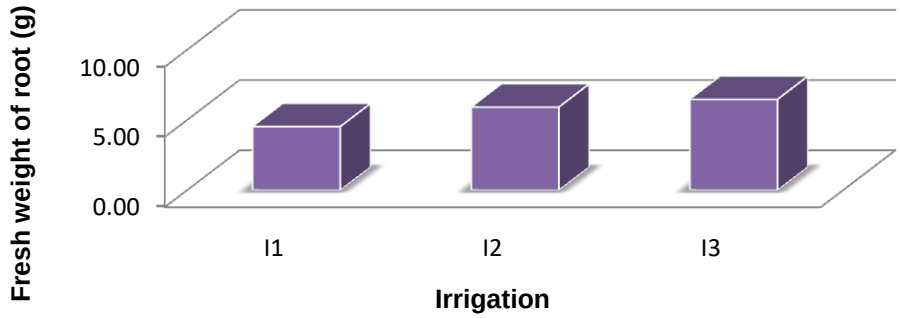


Fig. 8b: Effect of varieties on fresh weight of root (g) in french bean

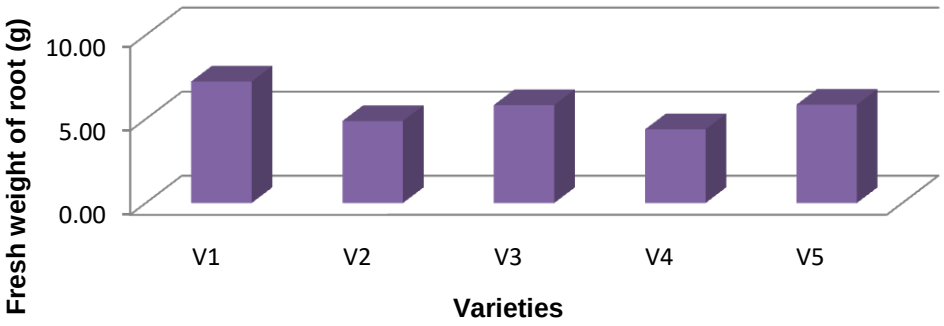
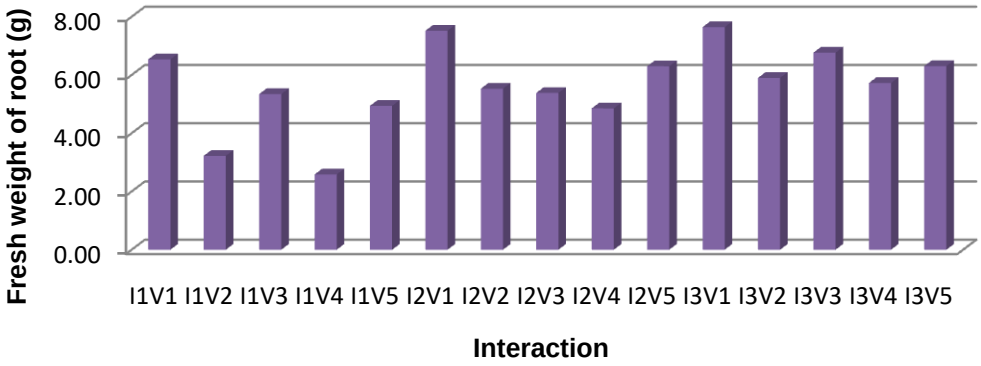


Fig. 8c: Interaction effect of irrigation levels and varieties on fresh weight of root (g) in french bean



4.1.7 Dry weight of root (g)

The data regarding dry weight of root presented in Table 14 and depicted in Fig. 9 revealed significant influence of irrigation levels and varieties.

The irrigation levels had imposed significance influence on dry weight of root (g). The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum dry weight of root (2.66 g) which was followed by I_2 (IW/CPE=0.8), whereas minimum dry weight of root (1.18 g) was recorded with the irrigation level I_1 (IW/CPE=0.60).

Among the varieties, V_1 (Arka Komal) registered maximum dry weight of root (2.23 g), which was followed by (1.96 g) in V_3 (Arka Sharath). Minimum dry weight of root (1.63 g) was recorded in case of variety V_4 (Kashi Rajhans).

Interactions effect of irrigation levels and varieties had non-significant influence on dry weight of root at all the growth stage in french bean.

Table 14: Effect of irrigation levels, varieties and their interactions on dry weight of root (g) in french bean

Irrigation levels (I)	**Dry weight of root (g)**					**MEAN**
	Varieties (V)					
	V_1	**V_2**	**V_3**	**V_4**	**V_5**	
I_1	1.38	1.31	1.24	0.85	1.12	**1.18**
I_2	2.22	1.38	2.01	1.42	1.32	**1.67**
I_3	3.08	2.42	2.62	2.61	2.55	**2.66**
MEAN	**2.23**	**1.70**	**1.96**	**1.63**	**1.66**	

	I	**V**	**I×V**
S. Em ±	0.07	0.08	0.13
CD at 5%	0.28	0.23	NS

Fig. 9a: Effect of irrigation levels on dry weight of root (g) in french bean

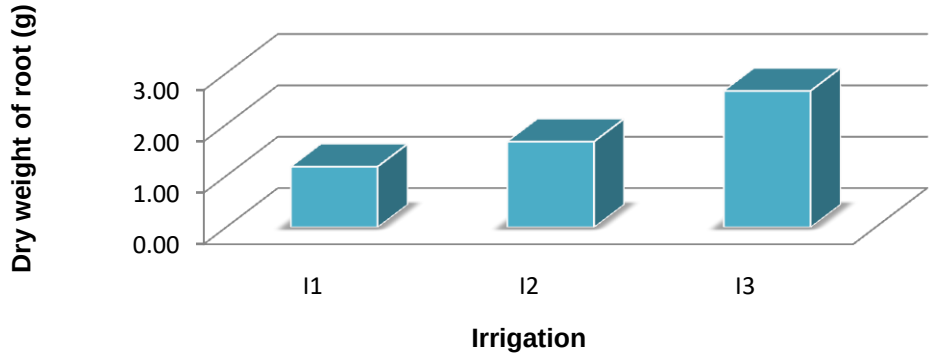


Fig. 9b: Effect of varieties on dry weight of root (g) in french bean

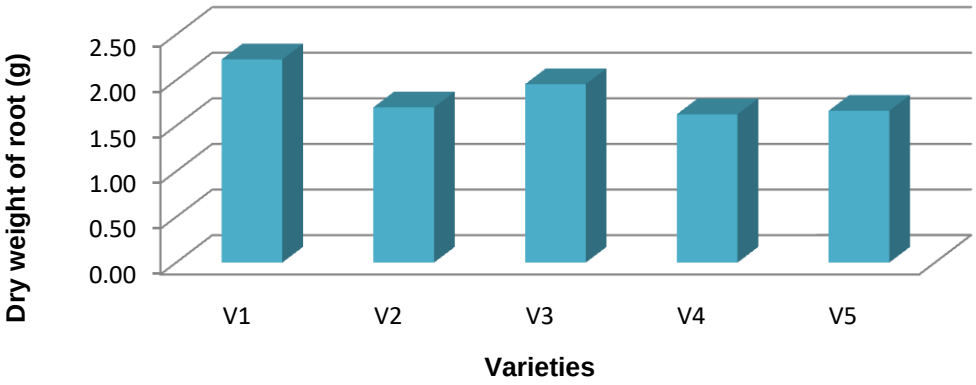
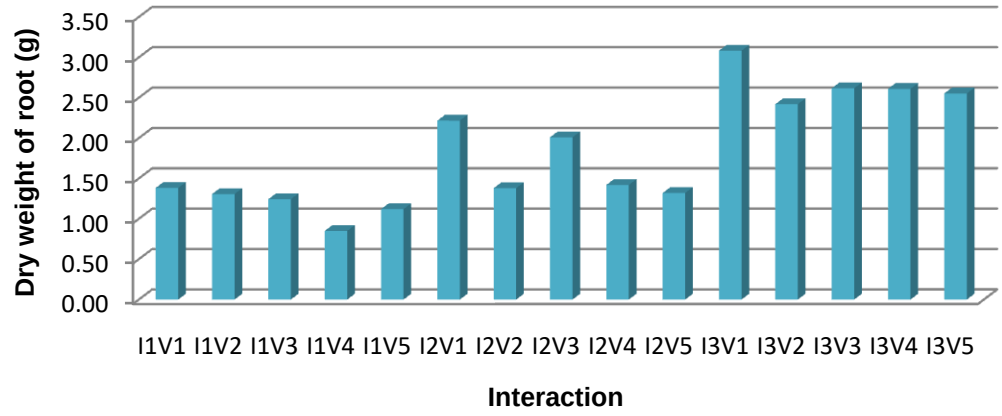


Fig. 9c: Interaction effect of irrigation levels and varieties on dry weight of root (g) in french bean



4.2 Phenological attributes

4.2.1 Number of node of first flower appearance

The data regarding number of node of first flower appearance presented in Table 15 and depicted in Fig.10 revealed significant influence of irrigation levels and varieties.

The irrigation levels had imposed significance influence on number of node of first flower appearance. The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum number of node of first flower appearance (5.56) which was followed by I_2 (IW/CPE=0.80). Whereas minimum number of node of first flower appearance (3.53) was recorded with the irrigation level I_1 (IW/CPE=0.60).

Among the varieties, V_4 (Kashi Rajhans) registered maximum number of node of first flower appearance (5.52) which was followed by $V_2>V_5>V_3$ in descending order. Minimum number of node (4.12) of first flower appearance was recorded in case of variety V_1 (Arka Komal).

Among the interactions of irrigation levels and varieties non-significant variation was imposed on number of node of first flower appearance in french bean.

Table 15: Effect of irrigation levels, varieties and their interactions on number of node of first flower appearance

Irrigation levels (I)	Number of node of first flower appearance					MEAN
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	
I_1	3.14	3.48	3.14	4.53	5.33	3.53
I_2	4.09	4.40	4.25	5.20	4.25	4.44
I_3	5.12	5.44	5.21	6.83	5.21	5.56
MEAN	**4.12**	**4.44**	**4.20**	**5.52**	**4.26**	

	I	V	I×V
S. Em ±	0.08	0.09	0.15
CD at 5%	0.30	0.26	NS

Fig. 10a. Effect of irrigation levels on number of node of first flower appearace

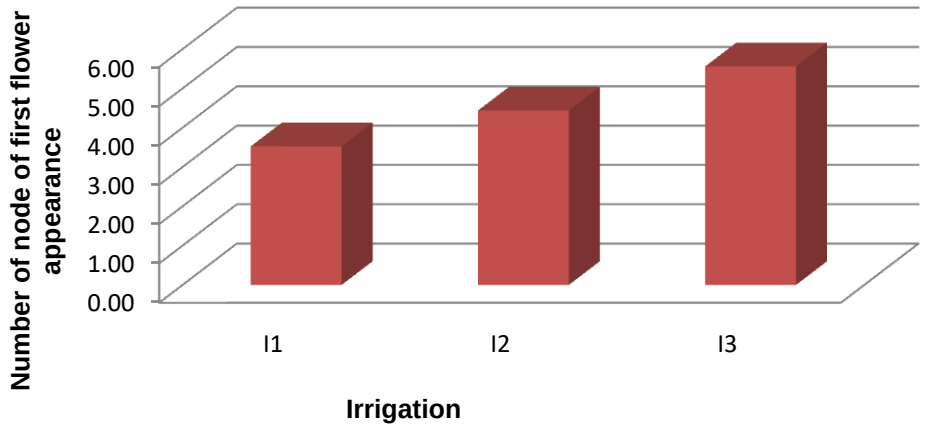


Fig. 10b Effect of varieties on number of node of first flower appearace

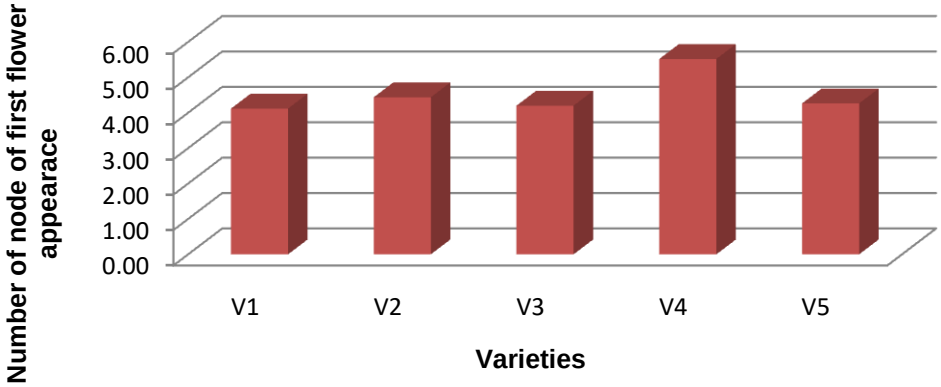
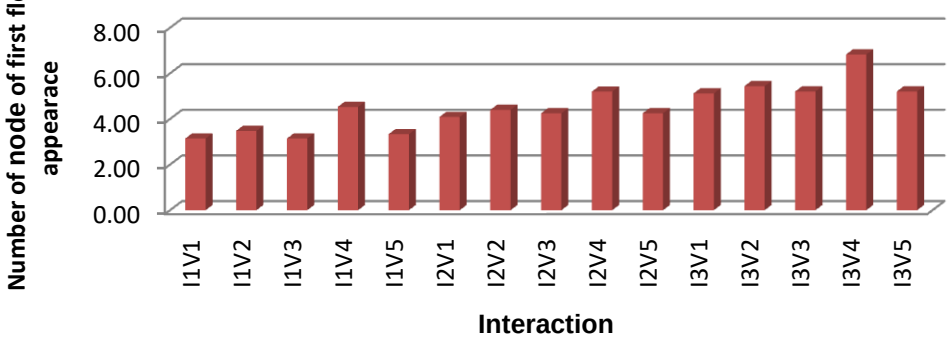


Fig. 10c Interaction effect of irrigation level and varieties number of node of first flower appearace



4.2.2 Days to first flower appearance

The data presented in Table 16 and depicted in Fig.11showed that day to first flower appearance was significantly influenced by irrigation levels and varieties.

The irrigation levels had imposed significance influence on days to first flower appearance. The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum days taken to first flower appearance (40.39 days) which was followed by I_2 (IW/CPE=0.80). Whereas minimum days taken to first flower appearance (35.71 days) was recorded with the irrigation level I_1(IW/CPE=0.60).

Among the varieties, V_4 (Kashi Rajhans) registered maximum number of node of first flower appearance (41.00 days) which was followed by $V_2>V_5>V_3$, Minimum days taken to first flower appearance (34.37 days) was recorded in case of variety V_1 (Arka Komal).

Among the interactions of irrigation levels and varieties non-significant variation was imposed on days taken to first flower appearance in french bean.

Table 16: Effect of irrigation levels, varieties and their interactions on days taken to first flower appearance

Irrigation levels (I)	Days taken to first flower appearance					MEAN
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	
I_1	32.38	37.57	33.54	38.40	36.65	35.71
I_2	34.43	38.33	35.42	40.15	36.41	36.95
I_3	36.29	42.41	38.27	44.45	40.52	40.39
MEAN	**34.37**	**39.44**	**35.74**	**41.00**	**37.86**	

	I	V	I×V
S. Em ±	0.71	0.94	1.63
CD at 5%	2.77	2.74	NS

Fig. 11a Effect of irrigation levels on days taken to first flower appearance

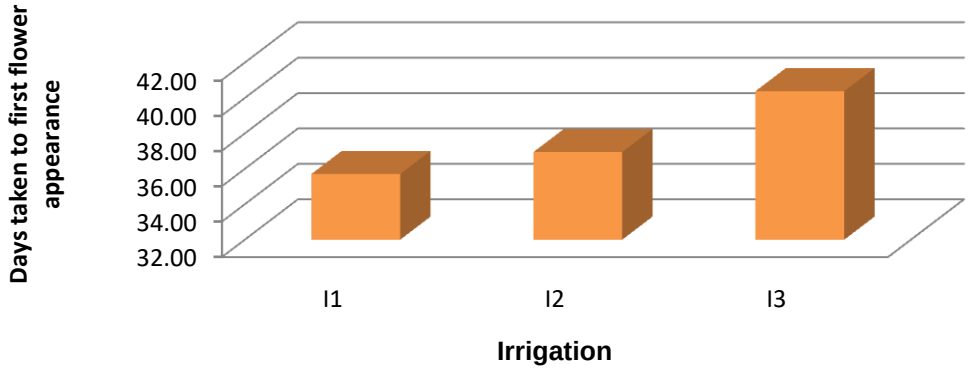


Fig 11b Effect of varieties on days taken to first flower appearance

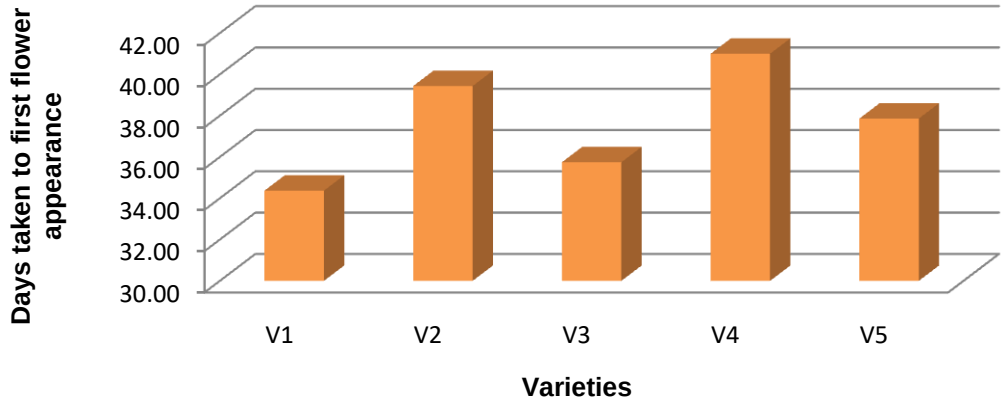
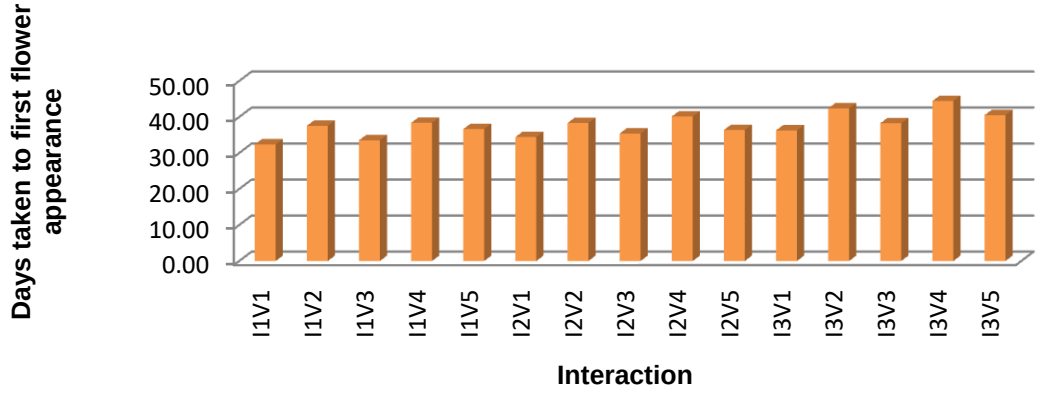


Fig. 11c Interaction effect of irrigation levels and varieties on days taken to first flower appearance



4.2.3 Days taken to 50 per cent flowering

The data regarding days taken to 50% flowering presented in Table 17 and depicted in Fig.11 revealed significant influence of irrigation levels and varieties.

The irrigation levels had imposed significance influence on days taken to 50% flowering. The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum days taken to 50% flowering (49.57 days) which was followed by irrigation level I_2 (IW/CPE=0.80). Whereas minimum days taken to 50% flowering (46.84 days) was recorded with the irrigation level I_1 (IW/CPE=0.60).

Among the varieties, V_4 (Kashi Rajhans) registered maximum days taken to 50% flowering (49.76 days) which was followed by V_2>V_5>V_3. Minimum days taken to 50% flowering (45.92 days) were recorded in case of variety V_1 (Arka Komal).

Among the interactions of irrigation levels and varieties non-significant variation was imposed on days taken to 50% flowering in french bean.

Table 17: Effect of irrigation levels, varieties and their interactions on days taken to 50% flowering in french bean

Irrigation levels (I)	Days taken to 50% flowering					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	46.52	47.55	49.39	48.39	46.32	**46.84**
I_2	46.77	47.80	45.64	48.64	46.57	**47.09**
I_3	44.18	51.26	49.40	52.48	50.51	**49.57**
MEAN	**45.82**	**48.87**	**46.81**	**49.84**	**47.80**	

	I	V	I×V
S. Em ±	0.19	0.93	1.62
CD at 5%	0.74	2.73	NS

Fig. 12a Effect of irrigation levels on days taken to 50% flowering

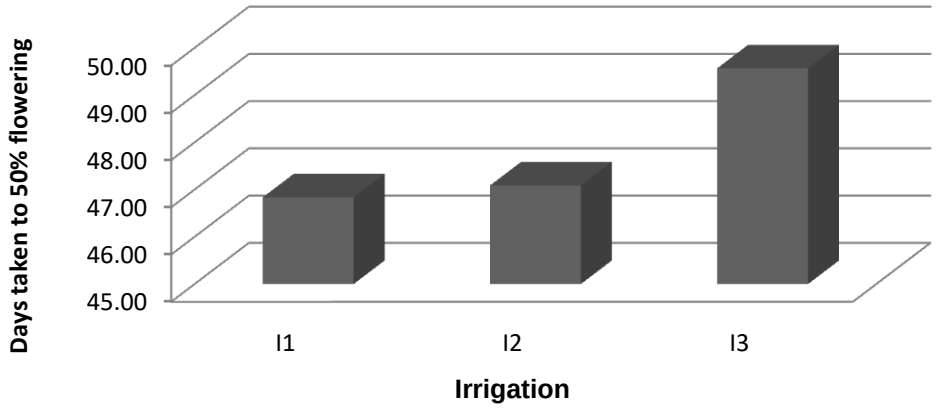


Fig. 12b Effect of varieties on days taken to 50% flowering

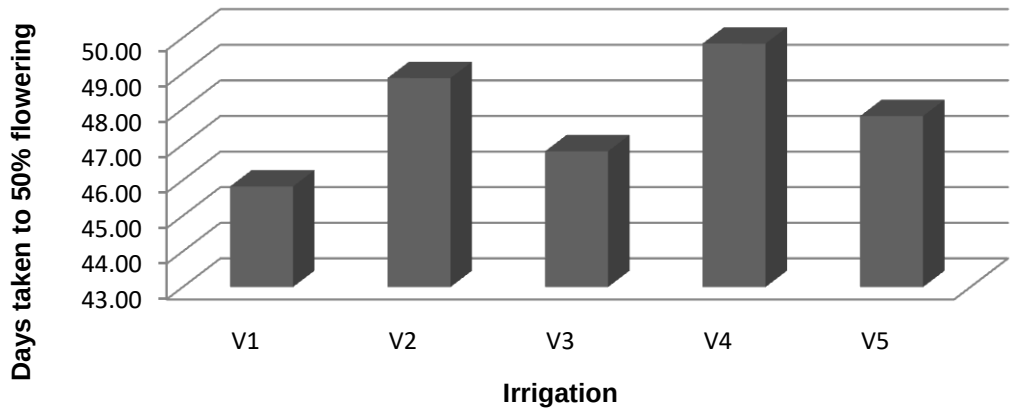
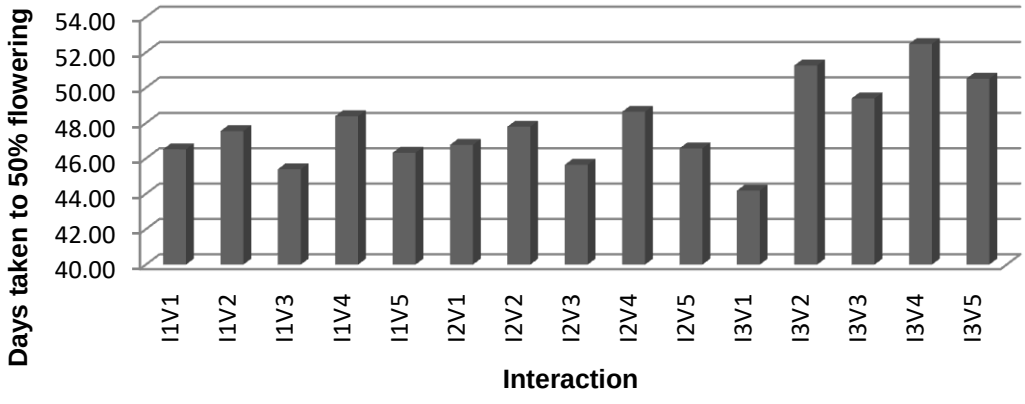


Fig. 12c Interaction effect of irrigation levels and varieties on days taken to 50% flowering



4.3 Yield parameters

Observations on number of pods per plant, number of seeds per podpod, pod length (cm), shelling (%), seed yield per plant (g), seed yield (q/ha) and harvesting index (%) were recorded and presented as follows:

4.3.1 Number of pods per plant

The number of pods per plant was recorded at harvesting stage and the data presented in Table 18 and Fig. 12 indicated significant effect of irrigation levels and varieties.

Highest number of pods per plant (15.27) was observed under the irrigation level I_3 (IW/CPE=1.00) which was followed by 12.96 per plant in I_2 (IW/CPE=0.80). Lowest number of pods per plant (11.49) was noted under the irrigation level I_1 (IW/CPE=0.60).

Variety V_1 (Arka Komal) resulted in the highest number of pod per plant (15.71), which was followed by V_3>V_5>V_2. Lowest number of pods (11.81) per plant was found with the variety V_4 (Kashi Rajhans).

Combined effect of irrigation regimes and varieties indicated significant effect on number of pods per plant in french bean.

Table 18: Effect of irrigation levels, varieties and their interactions on number of pods per plant in french bean

Irrigation levels (I)	Number of pods per plant					
	Varieties (V)					Mean
	V_1	V_2	V_3	V_4	V_5	
I_1	14..04	11.18	12.10	10.51	9.63	**11.49**
I_2	15.27	13.07	14.48	10.44	11.52	**12.96**
I_3	17.83	11.84	16.69	14.49	15.49	**15.27**
MEAN	**15.71**	**12.03**	**14.42**	**11.81**	**12.21**	

	I	V	I×V
S. Em ±	0.27	0.53	0.92
CD at 5%	1.09	1.56	NS

Fig. 13a Effect of irrigation levels on number of pods per plant in french bean

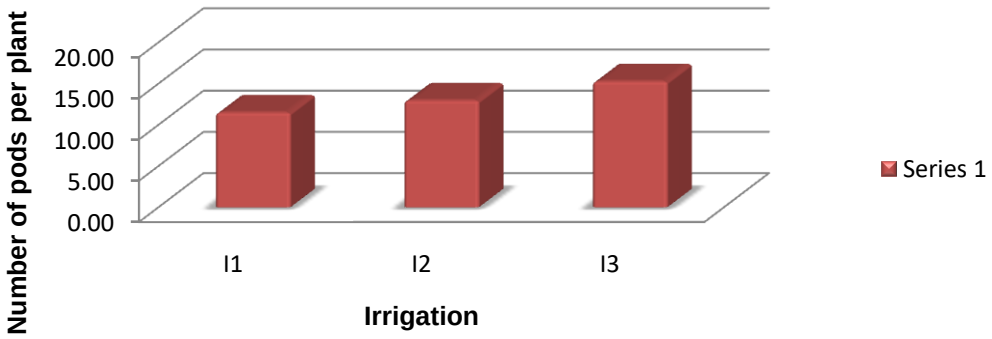


Fig. 13b: Effect of varieties on number of pods per plant in french bean

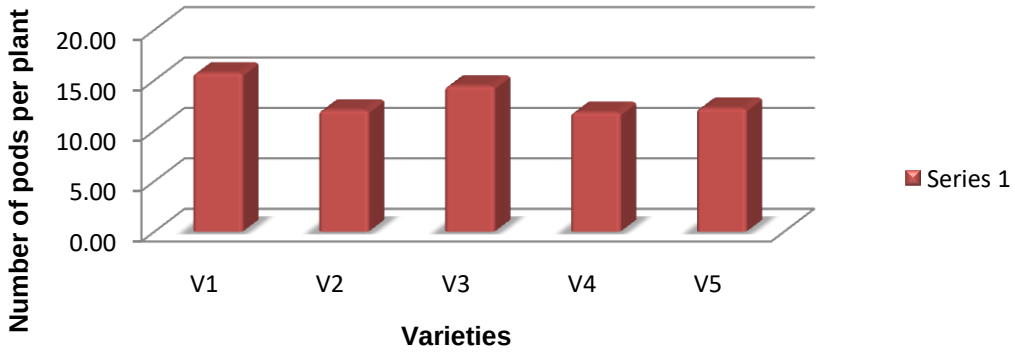
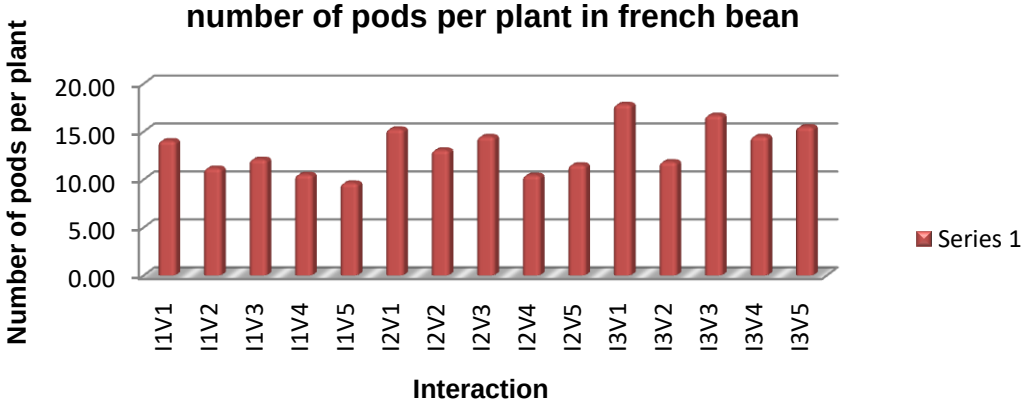


Fig. 13c: Interaction effect of irrigation levels and on number of pods per plant in french bean



4.3.2 Number of seeds per pod

The Table 19 and Fig. 13 showed significant effect of irrigation levels and varieties on number of seed per pod. Combined effect of irrigation level and varieties showed non-significant influence on number of seed per pod.

Irrigation levels exerted remarkable influence on number of seeds per pod. Highest number of seeds per pod (6.12) was observed under the irrigation level I_3 (IW/CPE=1.00) which was followed by 5.02 per plant I_2. Lowest number of seeds per pod was noted under irrigation level I_1 (4.76).

Variety V_1 (Arka Komal) resulted in the highest number of seeds per pod (5.82), which was followed by V_3>V_5>V_2. Variety V_4 (Kashi Rajhans) recorded lowest number of seeds (11.81) per pod.

Combined effect of irrigation regimes and varieties indicated non-significant effect on number of seeds per pod.

Table 19: Effect of irrigation levels, varieties and their interactions on number of seeds per pod

Irrigation levels (I)	Number of seed per pod					
	Varieties (V)					Mean
	V_1	V_2	V_3	V_4	V_5	
I_1	5.11	4.74	4.85	4.38	4.72	**4.76**
I_2	5.65	4.73	4.49	4.82	5.07	**4.95**
I_3	6.42	5.81	6.68	5.60	6.12	**6.12**
MEAN	**5.73**	**5.09**	**5.34**	**4.93**	**5.30**	

	I	V	I×V
S. Em ±	0.14	0.16	0.28
CD at 5%	0.57	0.48	NS

Fig. 14a: Effect of irrigation levels on number of seeds per pod in french bean

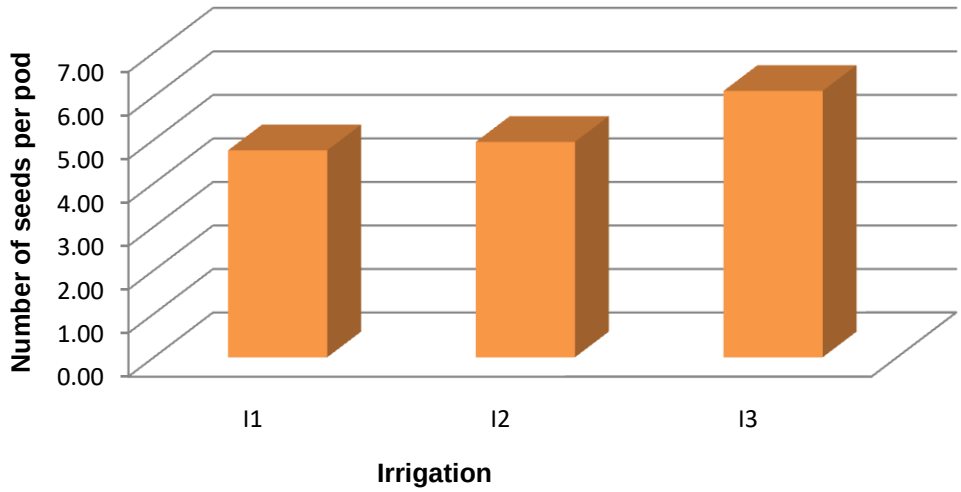


Fig. 14b: Effect of varieties on number of seeds per pod in french bean

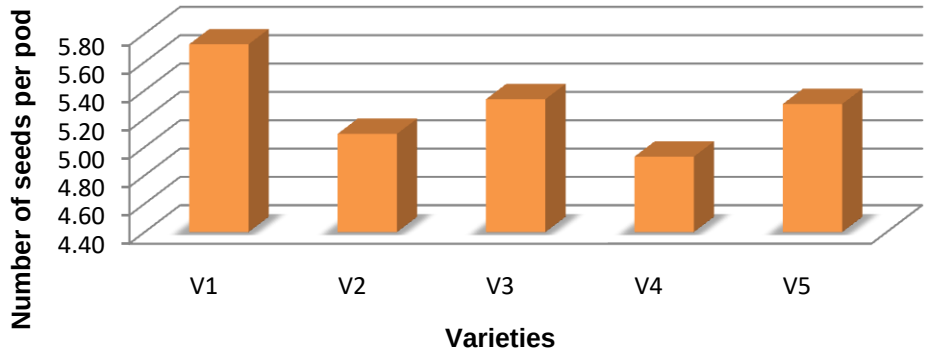


Fig. 14c: Interaction effect of irrigation levels and varieties on number of seeds per pod in french bean

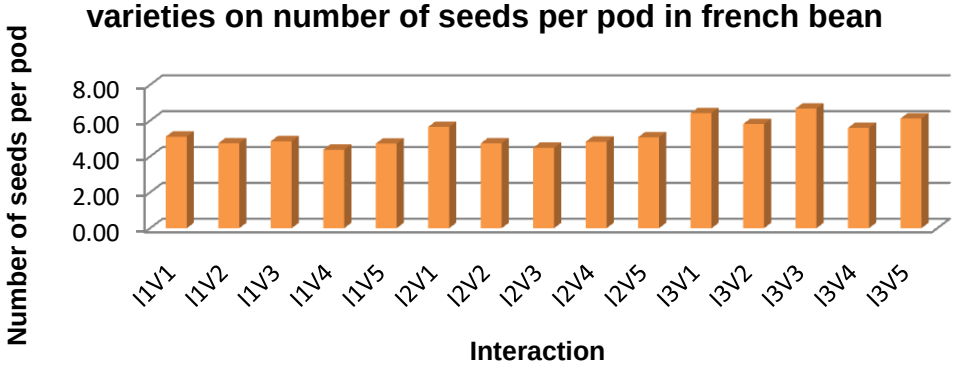




Plate 2:- Pods of different varieties of french bean

.3.3 Pod length (cm)

The data presented in Table 20 and depicted in Fig. 14 revealed that pod length was significantly influenced by irrigation regimes and varieties.

It can be observed from Table 4.12 and Fig.14 that the pod length of french bean was significantly affected by irrigation levels. Maximum pod length (12.35 cm) was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2 (11.16 cm) with the values of (IW/CPE=0.80) Minimum pod length (10.20 cm) was recorded in case of irrigation level I_1 (IW/CPE=0.60).

Amongst varieties, longest pod (12.45 cm) was found under variety V_1 (Arka Komal) which was followed by variety $V_3>V_5>V_2$ with a pod length of 11.84, 10.98 and 11.11 cm in french bean. Smallest pod (9.82 cm) was observed in case of variety V_4 (Kashi Rajhans).

Combined effect of irrigation levels and varieties registered non-significant effect on pod length (cm) in french bean under the study.

Table 20: Effect of irrigation levels, varieties and their interactions on pod length (cm) of french bean

Irrigation levels (I)	Pod length (cm)					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	11.52	10.52	10.49	8.69	9.80	**10.20**
I_2	12.99	10.85	11.45	9.53	10.98	**11.16**
I_3	12.84	11.96	13.57	11.23	12.15	**12.35**
MEAN	**12.45**	**11.11**	**11.84**	**9.82**	**10.98**	

	I	V	I×V
S. Em ±	0.27	0.32	0.55
CD at 5%	1.06	0.93	NS

Fig. 15a: Effect of irrigation levels on pod length (cm) in french bean

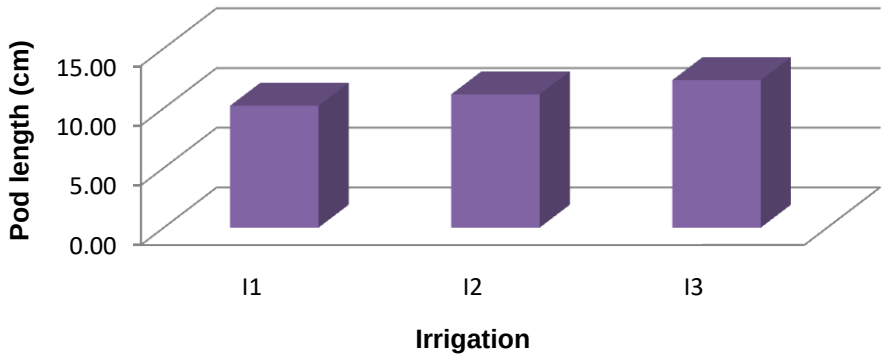


Fig. 15b: Effect of varieties on pod length (cm) in french bean

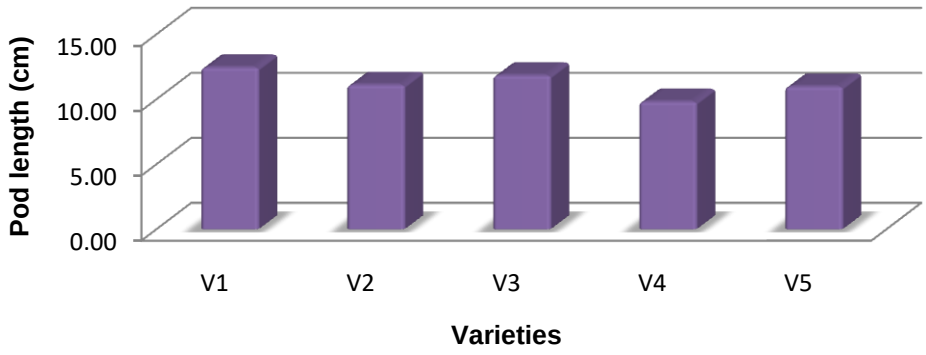
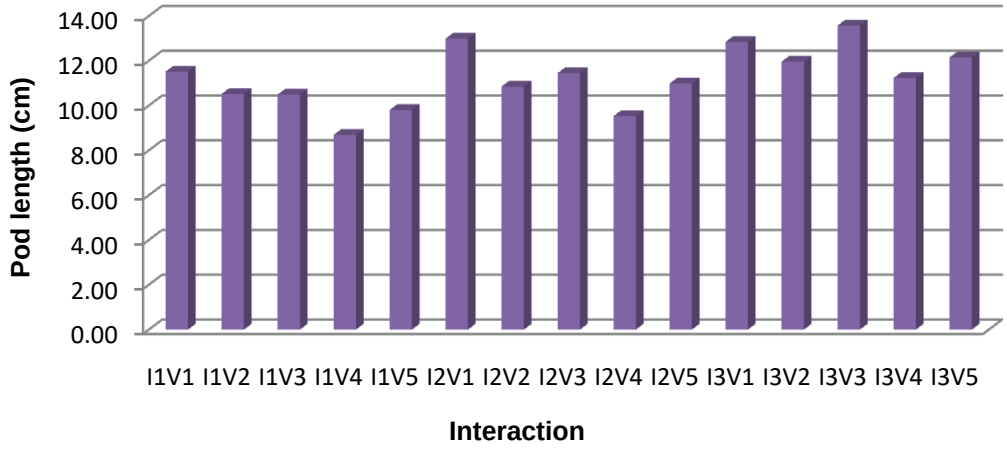


Fig. 15c: Interaction effect of irrigation levels and varieties on pod length (cm) in french bean



4.3.4 Shelling percentage

It is clear from the data presented in Table 210 and Fig. 15 that shelling (%) of french bean was significantly influenced by irrigation levels and varieties.

It can be observed from that the shelling (%) of french bean was significantly affected by irrigation levels. Maximum shelling (%) of 72.26% was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2 with the values of 67.39%. Minimum shelling percent (67.39%) was recorded in case of irrigation level I_1 (IW/CPE=0.60).

Among the varieties, maximum shelling (%) of 72.87% was recorded in the variety V_1 (Arka Komal), which was followed by variety $V_3>V_5>V_2$ with a values of 70.92, 70.00, 68.06 %, while the minimum shelling percent (66.54%) was found under variety V_4 (Kashi Rajhans).

Interactive effect of irrigation regimes and varieties exerted non significant influence on shelling (%).

Table 21: Effect of irrigation levels, varieties and their interactions on shelling (%) of french bean.

Irrigation levels (I)	Shelling percentage					MEAN
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	
I_1	71.12	65.81	68.85	64.23	66.92	**67.39**
I_2	73.61	67.13	71.34	65.99	68.88	**69.39**
I_3	73.87	71.25	72.56	69.41	74.20	**72.26**
MEAN	**72.87**	**68.06**	**70.92**	**66.54**	**70.00**	

	I	V	I×V
S. Em ±	0.77	1.38	2.39
CD at 5%	3.03	4.03	NS

Fig. 16a: Effect of irrigation levels on shelling(%) in french bean

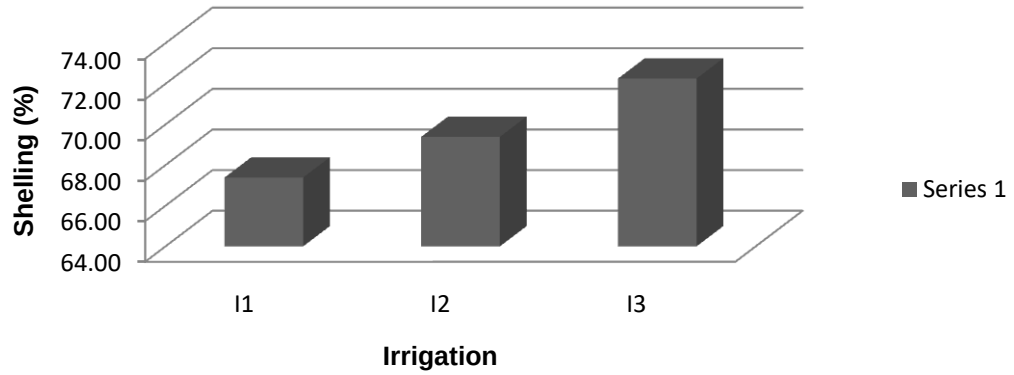


Fig. 16b: Effect of varieties on shelling (%) in french bean

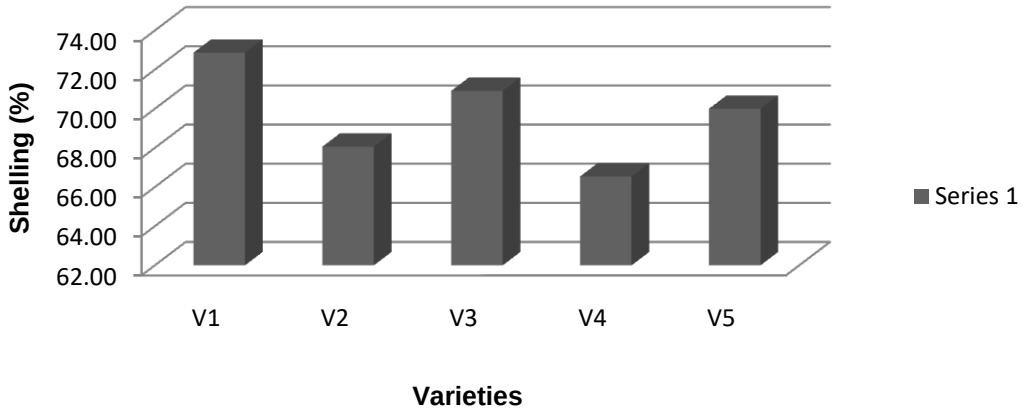
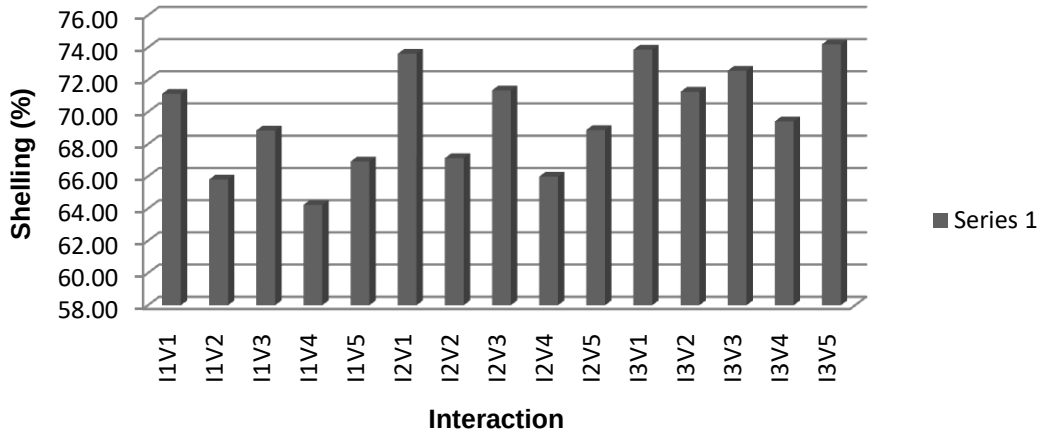


Fig. 16c: Interaction effect of irrigation levels and varieties on shelling (%) in french bean



4.3.5 Seed yield per plant (g)

The seed yield per plant was recorded at harvesting stage and the data presented in Table 22 and Fig. 16 indicated significant effect of irrigation regimes and varieties.

Irrigation levels exerted remarkable influence on seed yield (g) per plant. Highest seed yield per plant (18.14 g) was observed under the irrigation level I_3 (IW/CPE=1.00) which was followed by I_2 (IW/CPE=0.80). Lowest seed yield per plant (11.55 g) was noted under irrigation level I_1 ((IW/CPE=0.60).

Variety V_1 (Arka Komal) resulted in the highest seed yield per plant (17.38 g) which was followed by V_3>V_5>V_2. Lowest seed yield per plant (12.20 g) was found with the variety V_4 (12.20 g).

Combined effect of irrigation regimes and varieties indicated non significant effect on seed yield (g) per plant.

Table 22: Effect of irrigation levels, varieties and their interactions on seed yield (g) per plant of french bean.

Irrigation levels (I)	Seed yield per plant (g)					
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	Mean
I_1	14.31	10.66	12.68	8.52	11.56	**11.55**
I_2	17.45	13.38	15.31	11.70	14.59	**14.48**
I_3	20.37	17.33	18.20	16.37	18.43	**18.14**
MEAN	**17.38**	**13.79**	**15.40**	**12.20**	**14.86**	

	I	V	I×V
S. Em ±	0.72	0.51	0.89
CD at 5%	2.83	1.50	NS

Fig. 17a: Effect of irrigation levels on seed yield (g) per plant in french bean

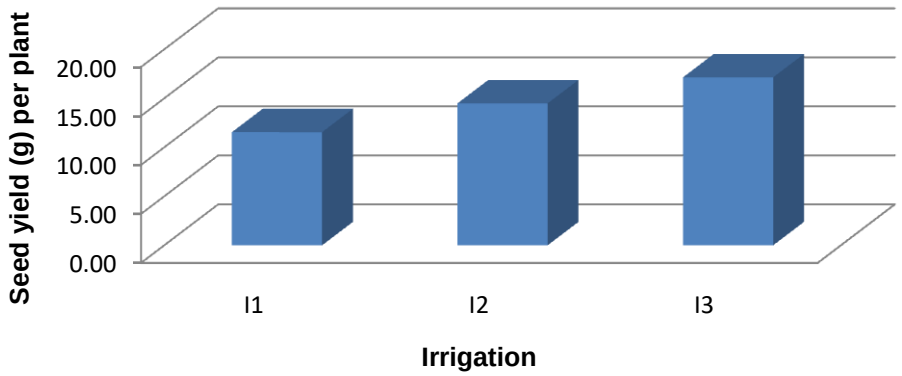


Fig. 17b: Effect of varieties on seed yield (g) per plant in french bean

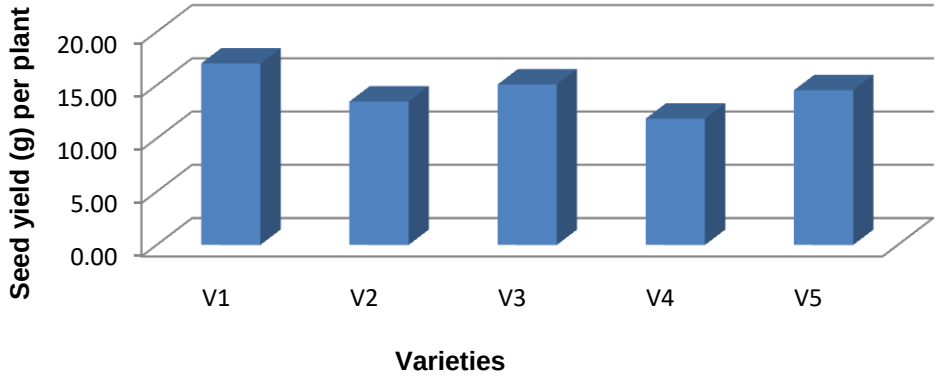
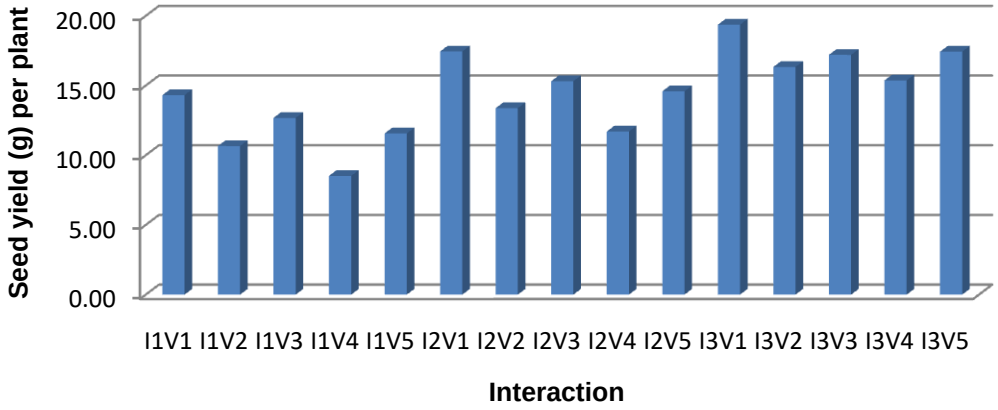


Fig. 17c: Interaction effect of irrigation levels and varieties on seed yield (g) per plant in french bean



4.3.6 Seed yield (q/ha)

It is clear from the data presented in Table 23 and Fig. 17 that seed yield (q/ha) of french bean was significantly influenced by irrigation levels and varieties

It can be observed that the seed yield of french bean was significantly affected by irrigation levels. Maximum seed yield (25.97 q/ha) was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2 and in descending order with the values of 20.73 q/ha. Minimum seed yield (16.53 q/ha) was recorded in case of Irrigation level I_1 (IW/CPE=0.60).

Among the varieties, maximum seed yield (24.87 q/ha) was recorded in the variety V_1 (Arka Komal), which was followed by variety $V_3>V_5>V_2$. While the minimum seed yield (17.46 q/ha) was recorded under variety V_4 (Kashi Rajhans).

Interactive effect of irrigation regimes and varieties exerted non-significant influence on seed yield (q/ha). The maximum seed yield (29.15 q/ha) was recorded under I_3V_1 (IW/CPE=0.85+ Arka Komal) treatment combination, which was followed by I_2V_1. While the minimum seed yield (12.20 q/ha) was registered under the treatment combination I_1V_4 (IW/CPE=0.60+ Kashi Rajhans).

Table 23: Effect of irrigation levels, varieties and their interactions on seed yield (q) per hectare of french bean.

Irrigation levels (I)	Seed yield (q) per hectare					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	20.49	15.26	18.15	12.20	16.55	**17.11**
I_2	24.97	19.15	21.92	16.75	20.88	**21.46**
I_3	29.15	24.81	26.06	23.43	26.38	**25.39**
MEAN	**25.25**	**19.94**	**22.32**	**17.58**	**21.52**	

	I	V	I×V
S. Em ±	1.06	0.76	1.32
CD at 5%	4.19	2.22	NS

Fig. 18a: Effect of irrigation levels on seed yield (q) per hectare in french bean

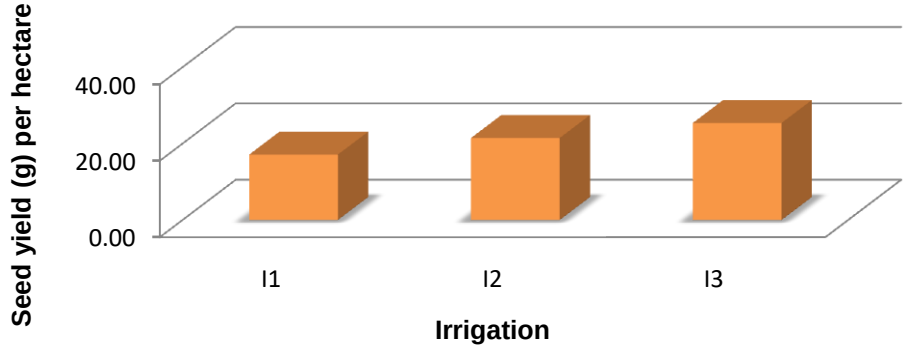


Fig. 18b: Effect of varieties on seed yield (q) per hectare in french bean

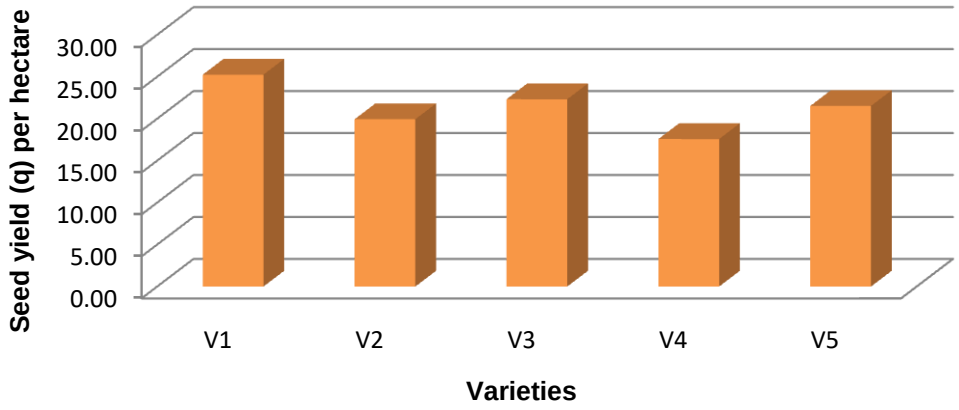
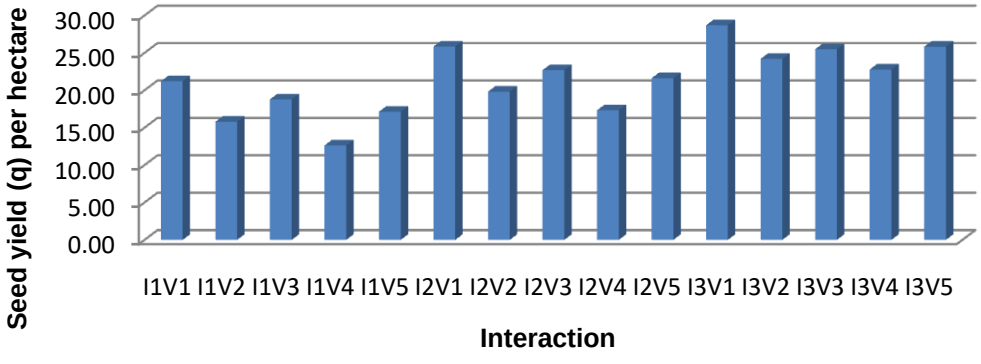


Fig. 18c: Interaction effect of irrigation levels and varieties on seed yield (g) per hectare in french bean



4.3.7 Harvest index (%)

The data regarding in harvest index of french bean are presented in Table 24 and Fig. 18. The findings revealed significant influence of irrigation regimes and varieties on harvest index in french bean.

Irrigation level I_3 (25.65%) revealed maximum harvest index (24.13%) followed by irrigation level I_2 (IW/CPE= 0.80). Whereas minimum harvest index (22.22%) was determined under the irrigation level I_1 (IW/CPE= 0.60).

Varieties indicated significant variation for harvest index. Maximum harvest index (26.94%) was recorded under variety V_1 (Arka Komal). It was followed by $V_3>V_5>V_2$ in descending order. Variety V_4 (Kashi Rajhans) recorded minimum harvest index (22.10%).

Combined effect of irrigation levels and varieties revealed non-significant influence on harvest index (%) in french bean.

Table 24: Effect of irrigation levels, varieties and their interactions on harvest index (%) of french bean.

Irrigation levels (I)	Harvest index (%)					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	25.48	21.27	22.09	20.51	21.72	**22.22**
I_2	26.90	23.51	25.94	21.47	22.81	**24.13**
I_3	28.43	23.69	26.80	24.32	24.99	**25.65**
MEAN	**26.94**	**22.84**	**24.95**	**22.10**	**23.18**	

	I	V	I×V
S. Em ±	0.41	0.44	0.77
CD at 5%	1.62	1.30	NS

Fig. 19a: Effect of irrigation levels on harvest index (%) in french bean

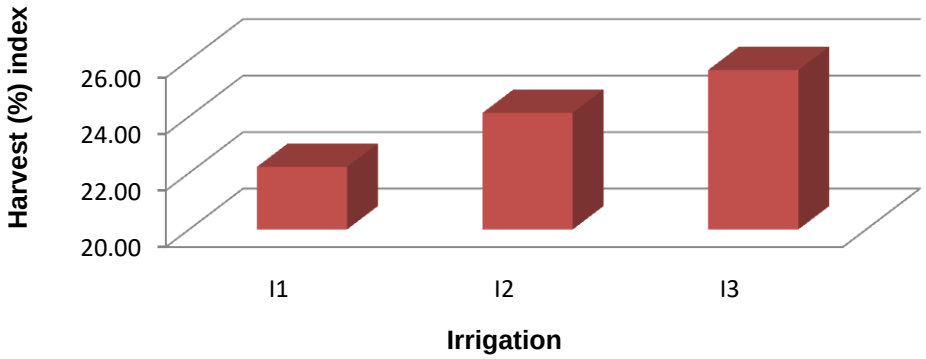


Fig. 19b: Effect of varieties on harvest index (%) in french bean

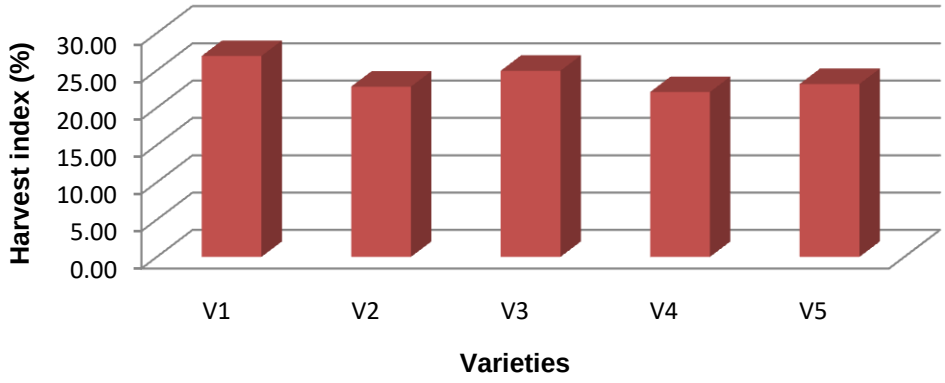
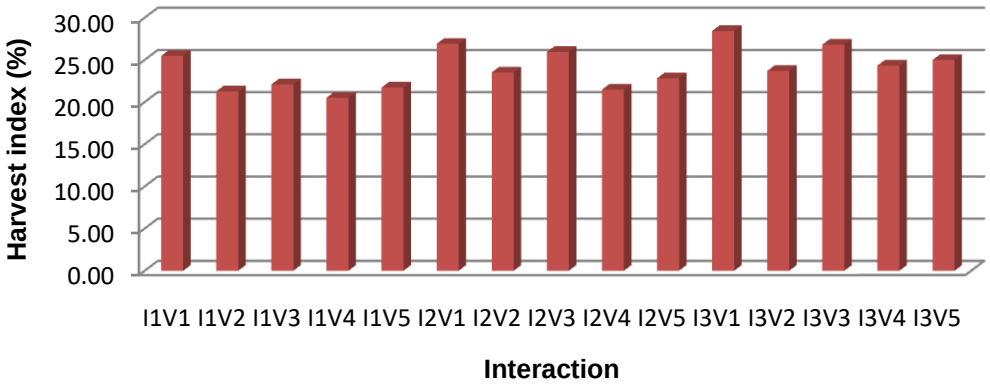


Fig. 19c: Interaction effect of irrigation levels and varieties on harvest index (%) in french bean



4.4 Quality parameter

4.4.1 Crude protein (%)

The results presented in Table 25 and illustrated in Fig.19 revealed significant effect of irrigation levels and varieties on crude protein in seeds of french bean.

Irrigation levels exhibited significant effect on crude protein seeds of french bean. Maximum crude protein in seeds (22.84%) was recorded under I_1 (IW/CPE=0.60). It was followed by irrigation level I_2 (IW/CPE=0.80) with the values of (20.07%). Minimum crude protein (2.34%) was recorded under irrigation level I_3 (IW/CPE=1.00).

Among the varieties, V_1 (Arka Komal) observed the maximum protein content (24.29%) which was followed by V_3>V_5>V_2. Minimum protein content (18.38%) was recorded in case of variety V_4 (Kashi Rajhans).

Combined effect of irrigation levels and varieties indicated non-significant effect on crude protein in seed of french bean.

Table 25: Effect of irrigation levels, varieties and their interactions on crude protein (%) in seed of french bean.

Irrigation levels (I)	Crude protein content (%) in seed					
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	Mean
I_1	26.03	21.53	24.09	20.08	22.49	**22.84**
I_2	24.49	19.40	23.33	18.56	22.37	**21.63**
I_3	22.34	19.36	21.42	16.49	20.75	**20.07**
MEAN	**24.29**	**20.10**	**22.95**	**18.38**	**21.87**	

	I	V	I×V
S. Em ±	0.51	0.47	0.81
CD at 5%	1.99	1.36	NS

Fig. 20a Effect of irrigation levels on crude protein in seed of french bean

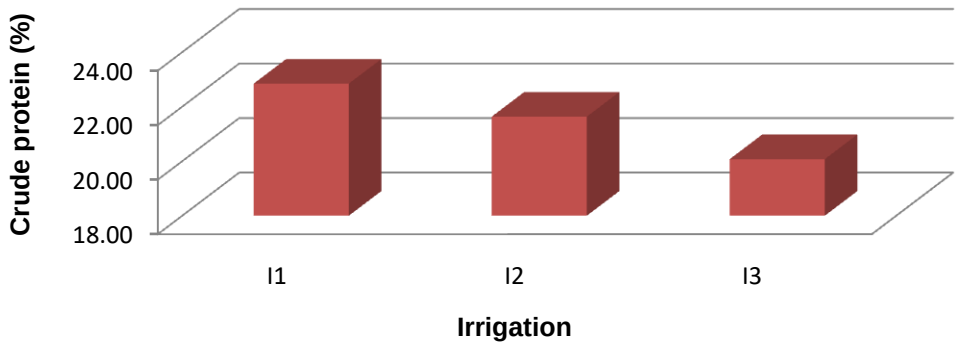


Fig. 20b Effect of varieties on crude protein in seed of french bean

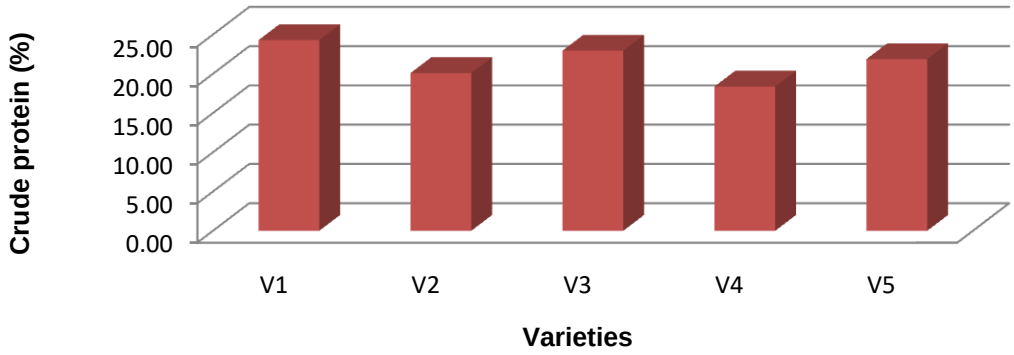
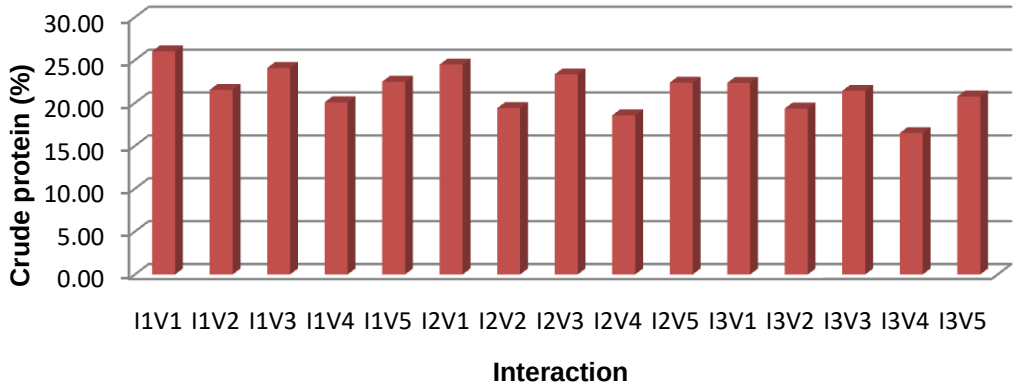


Fig. 20c Interaction effect of irrigation levels and varieties on crude protein in seed of french bean



4.4.2 Weight of 100 seed (g)

The results presented in Table 26 and illustrated in Fig. 20 revealed significant effect of irrigation levels and varieties on weight of 100 seed (g) of french bean.

Irrigation levels exhibited significant effect on weight of 100 seed (g) of french bean. Maximum weight of 100 seed (35.28 g) was recorded under irrigation level I_3 (IW/CPE=1.00). It was followed by irrigation level I_2 with the values of 33.57 g. Minimum weight of 100 seed (31.54 g) was recorded under irrigation level I_1 (IW/CPE=0.60).

Among the varieties, maximum weight of 100 seed (38.53 g) was determined with the variety V_1 (Arka Komal) which was followed by $V_3>V_5>V_2$ in descending order. Minimum weight of 100 seed (29.97 g) was recorded in case of variety V_4 (Kashi Rajhans).

Combined effect of irrigation levels and varieties indicated non-significant effect on weight of 100 seed (g) of french bean

Table 26: Effect of irrigation levels, varieties and their interactions on weight of 100 seed of french bean.

Irrigation levels (I)	Weight of 100 seed					MEAN
	Varieties (V)					
	V_1	V_2	V_3	V_4	V_5	
I_1	36.91	28.13	33.52	28.13	31.01	**31.54**
I_2	38.35	30.64	34.81	30.31	33.75	**33.57**
I_3	40.34	33.22	36.74	31.47	34.61	**35.28**
MEAN	**38.53**	**30.66**	**35.02**	**29.97**	**33.12**	

	I	V	I×V
S. Em ±	0.41	0.57	0.99
CD at 5%	1.61	1.67	NS

Fig. 21a: Effect of irrigation levels on weight of 100 seed (g) in french bean

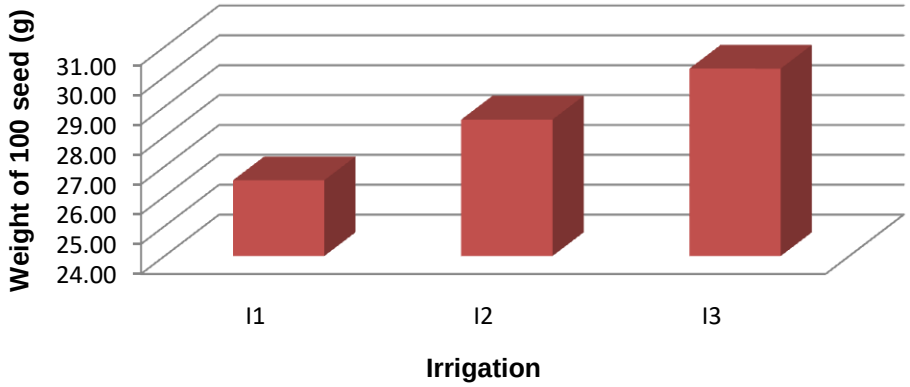


Fig. 21b: Effect of varieties on weight of (g) seed in french bean

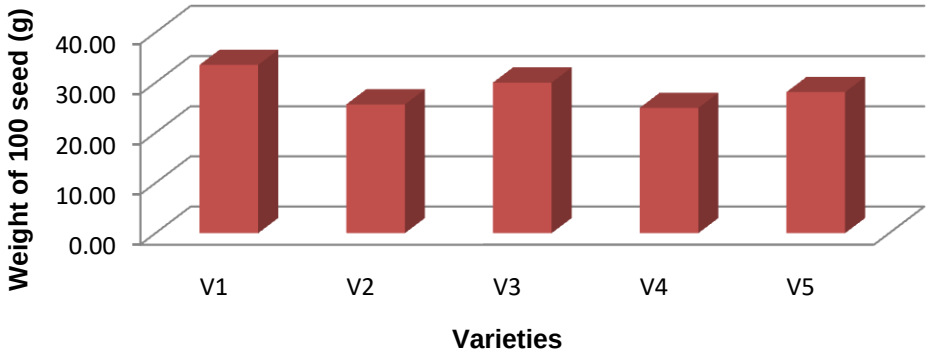
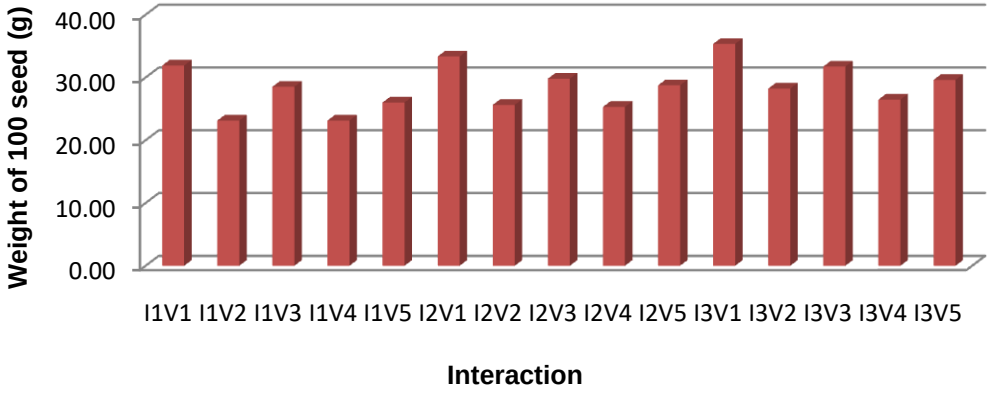


Fig. 21c: Interaction effect of irrigation levels and varieties on weight of 100 seed (g) in french bean



4.4.3 Germination (%)

The results presented in Table 27 and illustrated in Fig. 21 revealed significant effect of irrigation levels and varieties on germination (%) of french bean.

Irrigation levels exhibited significant effect on germination (%) of french bean. Maximum germination (89.97%) was recorded under irrigation level I_3 (IW/CPE=1.00). It was followed by I_2 (IW/CPE=0.80) with th e values of 86.65%. Minimum germination (83.38%) was recorded under irrigation level I_1 (IW/CPE=0.60).

Among the varieties, maximum germination (91.10%) was determined with variety V_1 (Arka Komal), which was followed by V_3>V_5>V_2. Variety V_4 (Kashi Rajhans) found minimum germination (83.87%).

Combined effect of irrigation levels and varieties indicated non- significant effect on germination (%) of french bean.

Table 27: Effect of irrigation levels, varieties and their interactions on germination (%) in seed of french bean.

Irrigation levels (I)	Germination (%)					
	Varieties (V)					MEAN
	V_1	V_2	V_3	V_4	V_5	
I_1	88.34	81.43	85.21	80.26	81.67	**83.38**
I_2	89.45	84.94	88.63	84.22	86.02	**86.65**
I_3	95.52	86.84	91.54	87.14	88.80	**89.97**
MEAN	**91.10**	**84.40**	**88.46**	**83.87**	**85.50**	

	I	V	I×V
S. Em ±	0.96	1.54	2.67
CD at 5%	3.80	4.50	NS

Fig. 22a: Effect of irrigation levels on germination (%) in seed of french bean

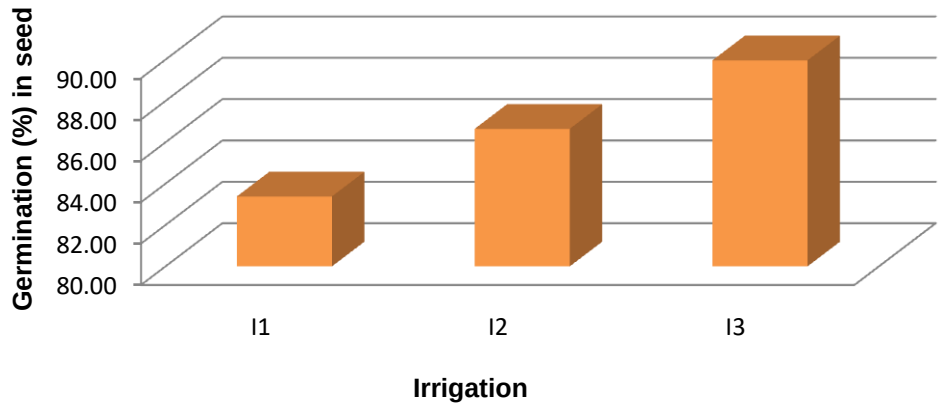


Fig. 22b: Effect of varieties on germination (g) in seed of french bean

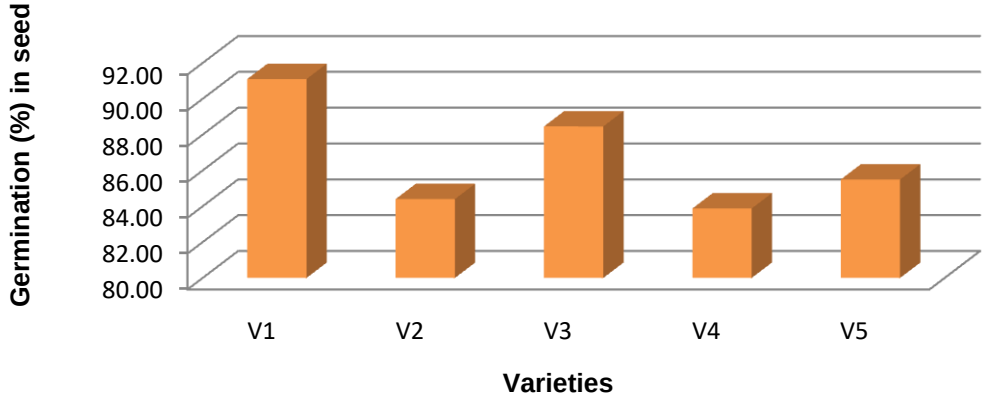
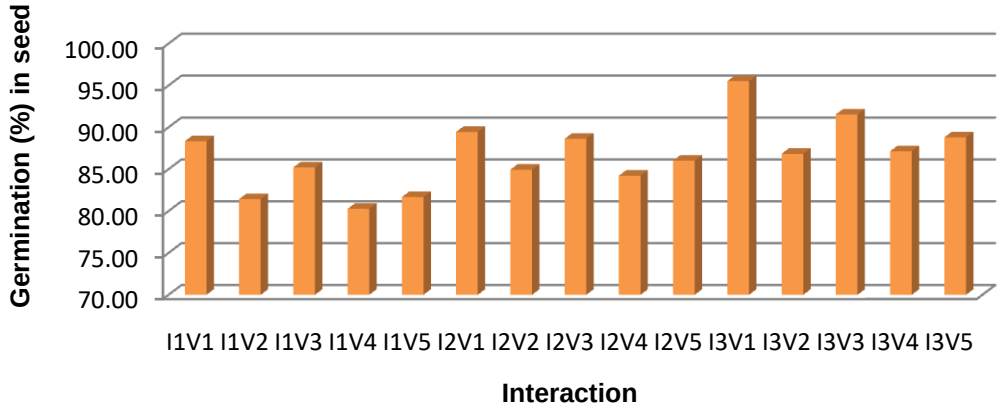


Fig. 22c: Interaction effect of irrigation levels and varieties on germination (%) in seed of french bean



4.5 Water utilization parameter

4.5.1 Water use efficiency (kg/ha-mm)

Water use efficiency (kg/ha-mm) was worked out for different treatments and presented in Table 28 and depicted in Fig. 22 revealed significant effect of irrigation regimes and varieties.

Maximum water use efficiency (6.04 kg/ha-mm) was recorded under irrigation level I_1 (IW/CPE=0.60) followed by irrigation levels I_2 with the values of 6.84 kg/ha-mm. While the minimum water use efficiency (6.66 kg/ha-mm) was registered under the irrigation level I_3 (IW/CPE=1.00).

Among the varieties, maximum water use efficiency (8.26 kg/ha-mm) was recorded with variety V_1 (Arka Komal). It was followed by V_3>V_5>V_2 with WUE of 7.31, 7.00 and 6.46 kg/ha-mm, while minimum water use efficiency (5.63 kg/ha-mm) was found with variety V_4 (Kashi Rajhans).

Combined effect of irrigation regimes and varieties exerted non-significant influence on water use efficiency (kg/ha-mm) in french bean.

Table 28: Effect of irrigation levels, varieties and their interactions on water use efficiency (kg/ha-mm) of french bean

Treatments	Water use efficiency (kg/ha-mm)					
Irrigation levels (I)	Varieties (V)					Mean
	V_1	V_2	V_3	V_4	V_5	
I_1	9.02	6.73	8.01	5.38	7.31	**7.29**
I_2	8.23	6.32	7.24	5.53	6.90	**6.84**
I_3	7.51	6.34	6.68	5.97	6.78	**6.66**
MEAN	**8.26**	**6.46**	**7.31**	**5.63**	**7.00**	

	I	V	I×V
S. Em ±	0.29	0.26	0.46
CD at 5%	1.160	0.781	NS

Fig. 23a: Effect of irrigation levels on water use efficiency (kg per hectare-mm) in french bean

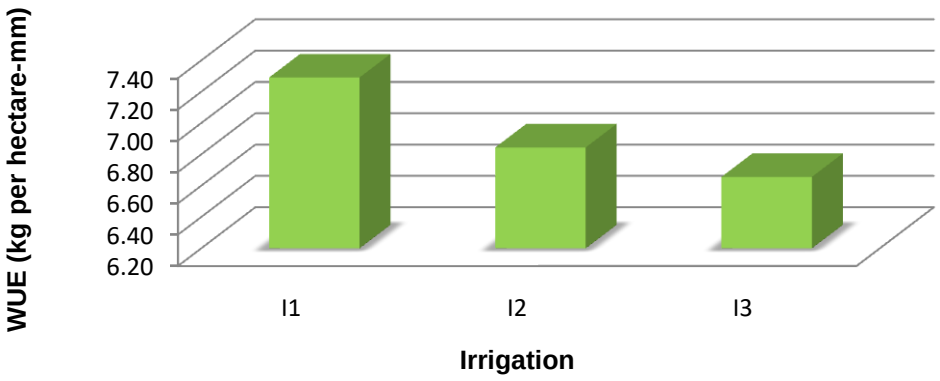


Fig. 23b: Effect of varieties on water use efficiency (kg per hectare-mm) in french bean

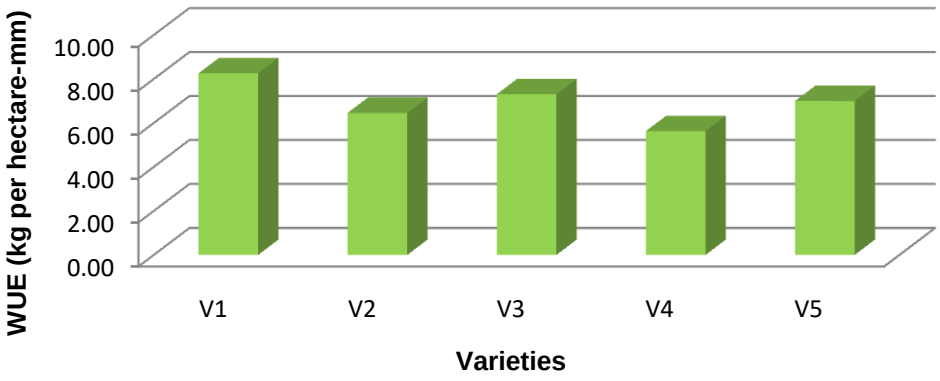
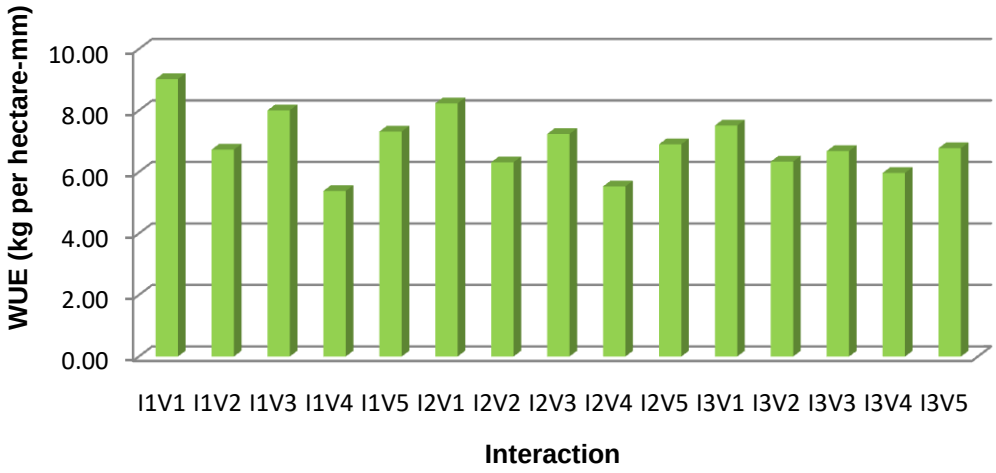


Fig. 23c: Interaction effect of irrigation levels and varieties on water use efficiency (kg per hectare-mm) in french bean



4.6 Economics of different treatments for okra production

Data presented in Table 29 and depicted in Fig. 24-26 revealed significant effect of irrigation levels and varieties on gross income, net income and B:C ratio, while interaction effect of irrigation levels and varieties had non significant effect on gross income, net income and B:C ratio in okra

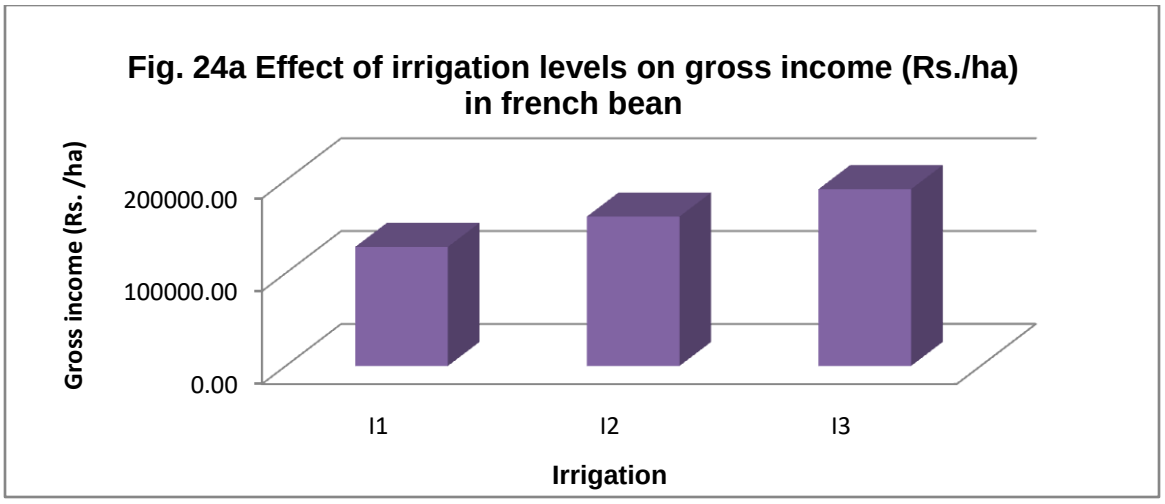
Irrigation levels exerted significant effect on gross income, net income and B:C ratio. Maximum gross income (190451.66Rs./ha), net income (Rs. 148091.66/ha) and B:C ratio (3.50) was recorded with of irrigation levels I_3 (IW/CPE= 1.00) which was significantly higher over other irrigation levels. It was followed by irrigation levels I_2. While minimum gross income (128299.45Rs./ha), net income (Rs. 88939.45/ha) and B:C ratio (2.26) was recorded under irrigation level I_1 (IW/CPE=0.60).

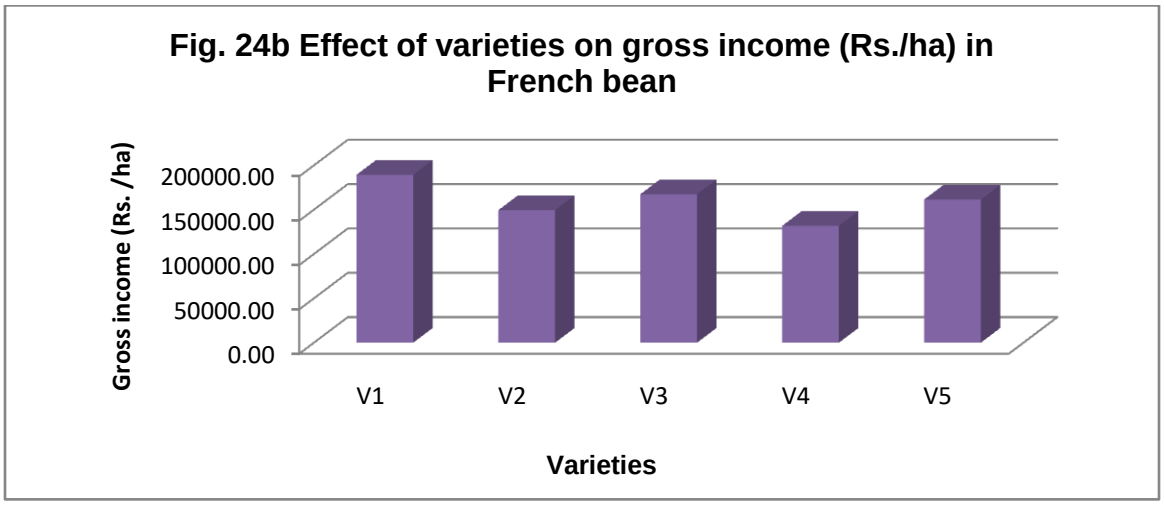
Highest gross income (Rs.189357.84/ha), net income (Rs. 148331.17/ha) and B:C ratio (3.60) was recorded in variety V_1 (Arka Komal). It was followed by V_3, V_5 and V_2. Lowest gross income (Rs 131814.68./ha), net income (Rs. 90788.02/ha) and B:C ratio (2.19) was noted in variety V_4 (Kashi Rajhans).

Interactive effect of irrigation levels and varieties had exerted non-significant influence on gross income, net income and B:C ratio. But numerically highest gross income (215184.97Rs./ha), net income (Rs. 172824.97) and B:C ratio (4.08) was realized in case of treatment combination I_3V_1, while lowest gross income (94666.57Rs./ha), net income (55306.57 Rs./ha) and B:C ratio (1.41) was found under I_1V_4 treatment combination.

Table 29: Effect of irrigation levels, varieties and their interactions on economics of seed production in French bean

Treatment	Economics of different treatments		
	Gross income (Rs.)	Net income (Rs.)	B:C ratio
Irrigation levels (I)			
I_1	128299.45	88939.45	2.26
I_2	160940.58	119580.58	2.89
I_3	190451.66	148091.66	3.50
S.Em ±	8012.04	8012.04	0.19
CD at 5%	31459.15	31459.15	0.74
Varieties (V)			
V_1	189357.84	148331.17	3.60
V_2	149523.84	108497.18	2.63
V_3	167382.55	126355.88	3.07
V_4	131814.68	90788.02	2.19
V_5	161407.25	120380.58	2.92
S.Em ±	5714.08	5714.08	0.14
CD at 5%	16678.22	16678.22	0.41
Interaction (I × V)			
I_1V_1	159036.88	119676.88	3.04
I_1V_2	118460.75	79100.75	2.01
I_1V_3	140851.71	101491.71	2.58
I_1V_4	94666.57	55306.57	1.41
I_1V_5	128481.35	89121.35	2.26
I_2V_1	193851.66	152491.66	3.69
I_2V_2	148629.48	107269.48	2.59
I_2V_3	170147.98	128787.98	3.11
I_2V_4	129999.87	88639.87	2.14
I_2V_5	162073.91	120713.91	2.92
I_3V_1	215184.97	172824.97	4.08
I_3V_2	181481.30	139121.30	3.28
I_3V_3	191147.96	148787.96	3.51
I_3V_4	170777.61	128417.61	3.03
I_3V_5	193666.47	151306.47	3.57
S.Em ±	9897.08	9897.08	0.24
CD at 5%	**NS**	**NS**	**NS**


Fig. 24a Effect of irrigation levels on gross income (Rs./ha) in french bean
Gross income (Rs. /ha)
200000.00
100000.00
0.00
I1
I2
I3
Irrigation


Fig. 24b Effect of varieties on gross income (Rs./ha) in French bean
Gross income (Rs. /ha)
200000.00
150000.00
100000.00
50000.00
0.00
V1
V2
V3
V4
V5
Varieties

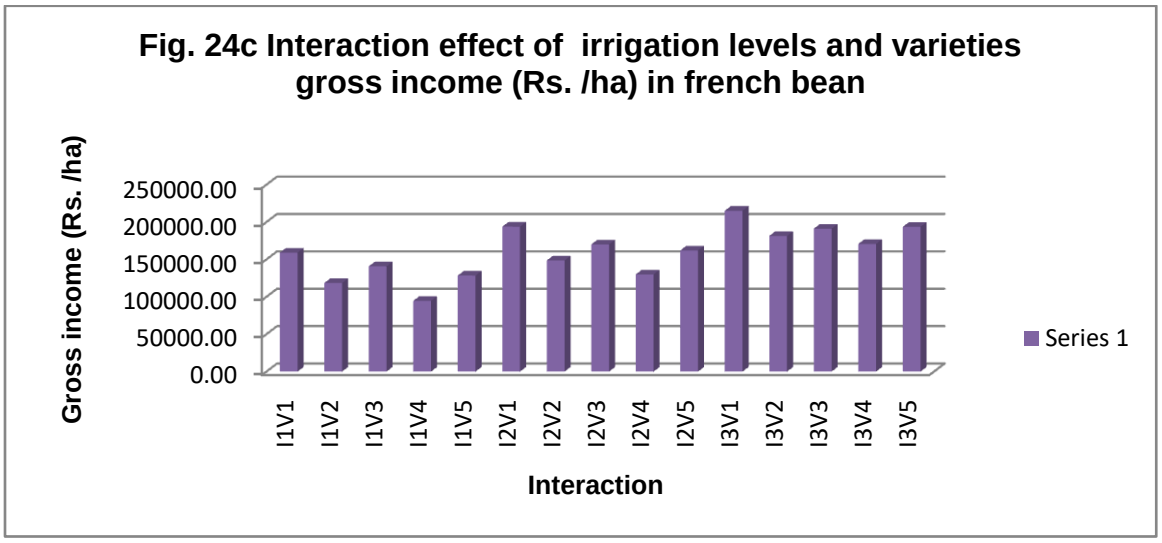

Fig. 24c Interaction effect of irrigation levels and varieties gross income (Rs. /ha) in french bean
Gross income (Rs. /ha)
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
I1V1
I1V2
I1V3
I1V4
I1V5
I2V1
I2V2
I2V3
I2V4
I2V5
I3V1
I3V2
I3V3
I3V4
I3V5
Interaction
Series 1

Fig. 25a Effect of irrigation levels on net income (Rs. /ha in french bean

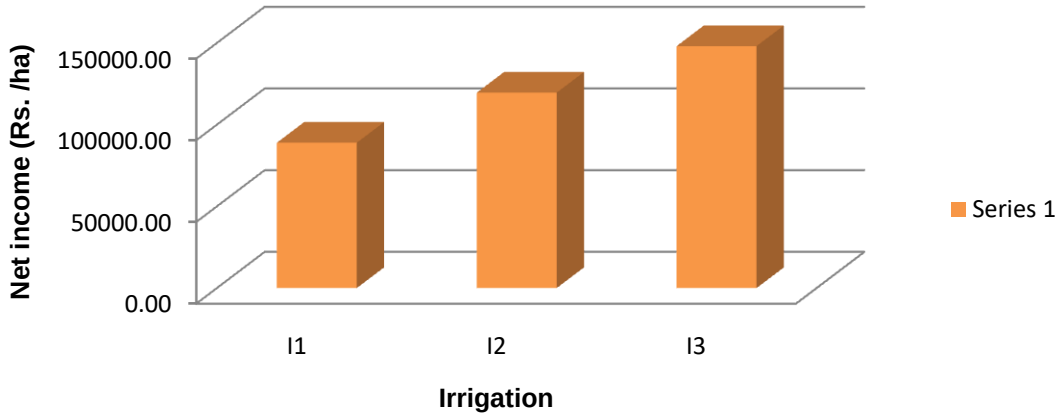


Fig. 24b Effect of varieties on net income (Rs. /ha in french5bean

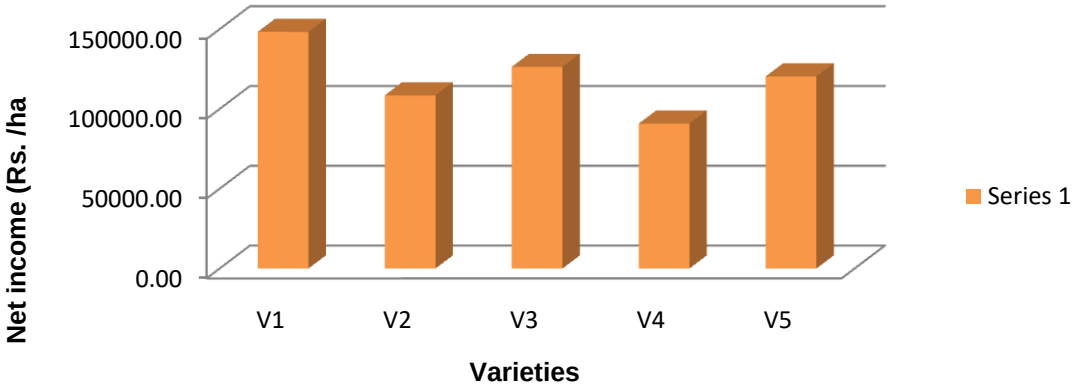


Fig. 25c Interaction effect of irrigation levels and varieties on net income (Rs. /ha in french bean

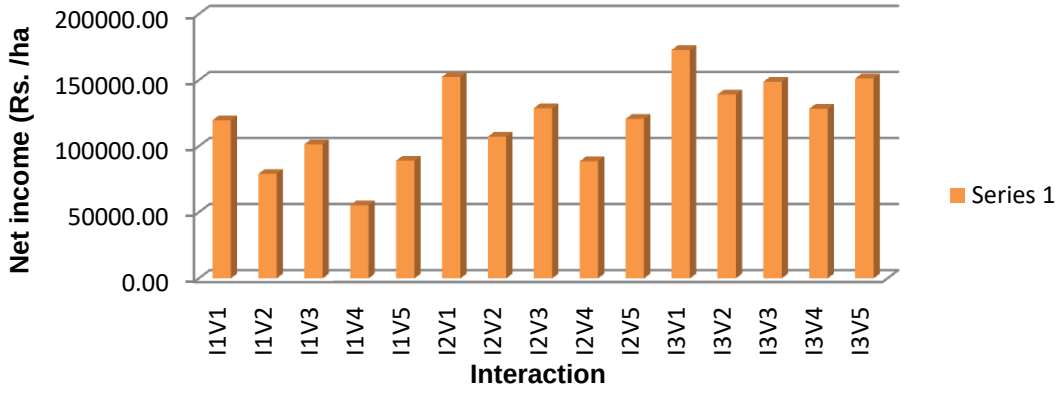


Fig. 26a Effect of irrigation levels on B:C ratio in french bean

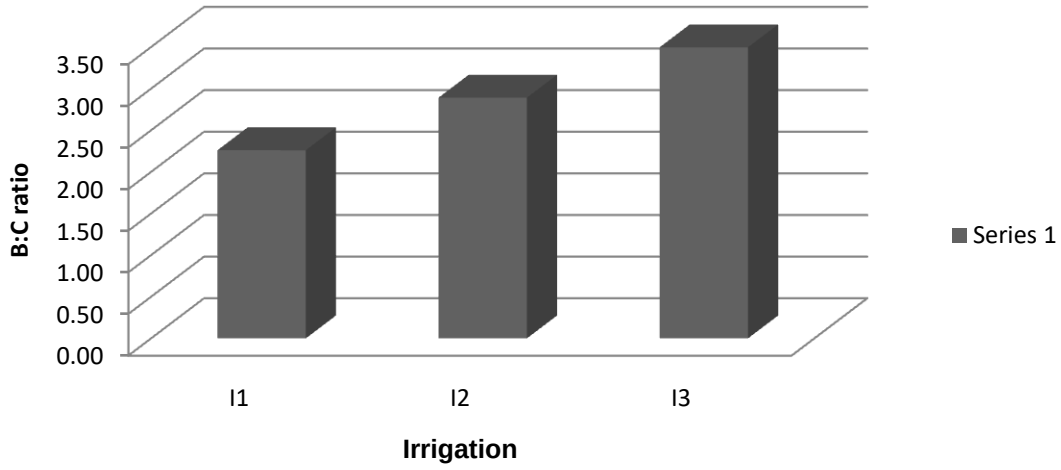


Fig. 26b Effect of varieties on B:C ratio in french bean

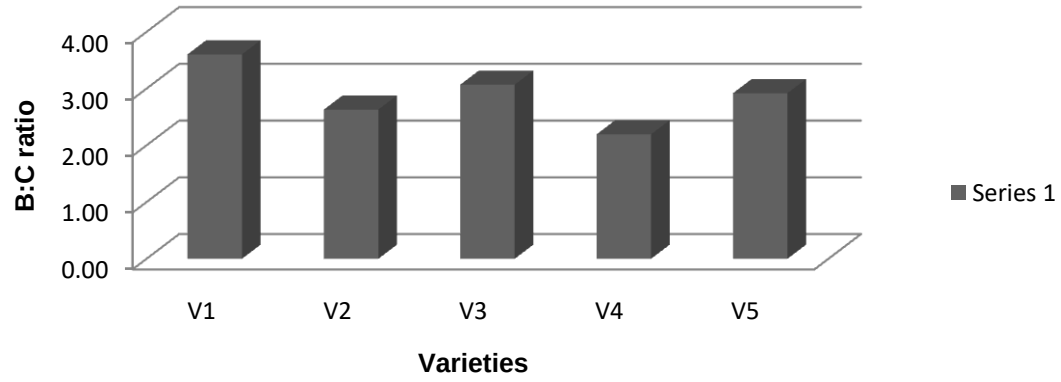
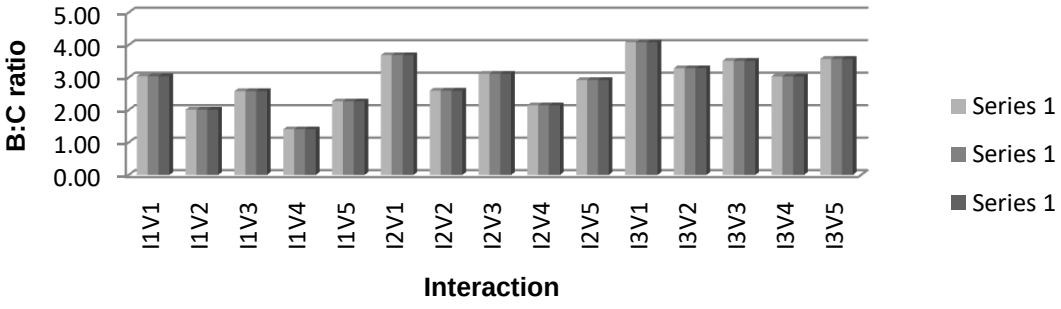


Fig. 26c Interaction effect of irrigation levels and varieties B:C ratio in french bean



CHAPTER- V

DISCUSSION

Chapter - V

DISCUSSION

The results of the present experiment entitled “Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (Phaseolus vulgaris L.)” are discussed and illustrated in the light of the findings of earlier workers here under following headings:

4.1 Growth Parameters

Observations on plant height, number of leaves per plant, number of branches per plant were recorded at 30, 45 and 60 DAS. Fresh weight of shoot, dry weight of shoot, fresh weight of root and dry weight of root were recorded at harvesting stage, are presented as follows:

Plant height was recorded at 30, 45 and 60 DAS (days after sowing). The results revealed that significant influence on plant height with irrigation levels and varieties of french bean.

It was observed that the plant height of french bean was significantly affected by irrigation levels. Maximum plant height was found with irrigation level I_3 (IW/CPE=1.00) which was followed by irrigation level I_2 (IW/CPE= 0.80) at 30, 45 and 60 DAS. Minimum plant height of was observed under the irrigation level I_1 (IW/CPE=0.60) at 30, 45 and 60 days after sowing. The increase in the plant height under treatment I_3 (IW/CPE=1.00) might be due to optimum supply of soil moisture near root zone which improving the nutrient uptake and translocation which ultimately related with the plant growth and development in terms of plant height due to frequent irrigation. Optimum soil moisture supply increased the cell division and cell expansion and there by stem elongation which virtually increased the plant growth in terms of plant height. Similar findings have been reported by Abdel-Mawgoud (2006) and Tyagi *et al*. (2012).

Maximum plant height recorded at 30, 45 and 60 DAS was respectively with the variety V_1 (Arka Komal) which was superior over the other varieties,

while minimum plant height of was recorded under V_4 (Kashi Rajhans) at 30, 45 and 60 DAS. These results are in accordance with the findings of Moniruzzaman *et al*. (2007), Rahman *et al*. (2012) and Meena *et al.* (2018).

Combined effect of irrigation levels and varieties had showed non-significant influence on plant height at all the stages of growth under the study in french bean**.**

Number of leaves per plant was recorded at 30, 45 and 60 days after sowing. The data revealed significant effect of irrigation levels and varieties on number of leaves per plant at all the growth stages.

Irrigation levels had exerted significant effect on number of leaves per plant at all the growth stages. Among the irrigation levels, I_3 (IW/CPE=1.00) recorded maximum number of leaves per plant at all the growth stages. It was followed by irrigation level I_2 (IW/CPE=0.80). Minimum number of leaves per plant were noted under irrigation level I_1 (IW/CPE=0.60). These findings are in agreement with the findings of El-Noemani *et al.* (2010), Gupta *et al.* (23017) and Saleh *et al*. (2018).

Varieties exerted significant effect on number of leaves per plant. Maximum number of leaves per plant was recorded under variety V_1 (Arka Komal), which was followed by V_3 (Arka Sharath). Minimum number of leaves was recorded in case of variety V_4 (Kashi Rajhans) which were per plant at 30, 45 and 60 DAS, respectively. Probable reasons for such varietal difference in number of leaves may be due to primitive effects of genotypes and such differences in french bean varieties were also observed by earlier research workers (Maske *et al*., 2009 and Santhi *et al*., 2015)

Combined effect of irrigation levels and varieties had non-significant effect on number of leaves per plant.

Perusal of data revealed significant influence of irrigation levels and varieties on number of branches per plant. Interaction effect of irrigation levels

and varieties had non- significant influence on number of branches per plant in french bean.

Every successive increase in irrigation regime increased the number of branches per plant significantly at all the growth stages. The maximum number of branches per plant were recorded under irrigation level I_3 (IW/CPE=1.00) at all the growth stages. It was followed by irrigation level I_2 (IW/CPE=0.80). Minimum number of branches per plant i.e. were noted under irrigation level I_1 (IW/CPE=0.60). It might be due to significant improvement in crop growth attributes, as a result of favourable soil moisture availability to the crop. These findings are corroborated with those reported by Singh *et al.* (2014), Gopal *et al.* (2015) and Saleh *et al*. (2018).

Varieties had significant effect on number of branches per plant. Maximum number of branches per plant was recorded under variety V_1 (Arka Komal), which was followed by variety V_3 (Arka Sharath). Minimum number of branches was recorded in case of variety V_4 (Kashi Rajhans). Similar findings were reported by Maske *et al.* (2009), Santhi *et al*. (2015) and Sharma *et al.* (2016).

Combined effect of irrigation levels and varieties showed non- significant effect on number of branches at all the growth stage in french bean.

Fresh and dry weight of shoot revealed significant effect of irrigation levels and varieties. The irrigation level I_3 (IW/CPE=1.00) recorded maximum fresh and dry weight of shoot. It was followed by I_2 (IW/CPE=0.80). Application of I_1 (IW/CPE= 0.60) irrigation level found minimum fresh and dry weight of shoot in french bean. The increment in number of leaves must have led to an increment in leaf area hence higher intercepted light and photosynthesis. Also increasing irrigation rate may increase water availability in the root zone resulting in improving plant water status and better stomatal conductance which eventually reflects on photo assimilate production. These effects are translated in terms of total fresh and dry weights of the plant which showed a positive response to increasing irrigation level (Abdel-Mawgoud, 2006). Similar findings were reported by El-Mogi *et al.* (2012) and Saleh *et al.* (2018).

Maximum fresh and dry weight of shoot was found with variety V_1 (Arka Komal), It was followed by $V_3 > V_5 > V_2$ in descending order. Minimum fresh and dry weight of shoot was observed with variety V_4 (Kashi Rajhans). These findings are corroborated with those of Saleh *et al.* (2018).

Combined effect of irrigation regimes and varieties imposed non-significant effect on fresh and dry weight of shoot in french bean.

Fresh and dry weight of root revealed significant effect of irrigation levels and varieties. Among the irrigation treatments, irrigation level I_3 (IW/CPE=1.00) recorded maximum fresh and dry weight of root followed by irrigation level I_2 (IW/CPE=0.80). Application of I_1 (IW/CPE=0.60) irrigation level found minimum fresh and dry weight of root in french bean. This observation is in agreement with the findings of El-Nemani *et al.* (2015) and Gopal *et al.* (2015) French bean.

Maximum fresh and dry weight of root was found with variety V_1 (Arka Komal). It was followed by in V_3 (Arka Sharath). Minimum fresh and dry weight of root was recorded with variety V_4 (Kashi Rajhans). The difference might be due to the different genetic potential of every variety (El-Noemani *et al*., 20110).

Combined effect of irrigation regimes and varieties imposed non-significant effect on fresh and dry weight of root (g) in french bean.

The irrigation levels had imposed significance influence on number of node of first flower appearance. The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum number of node of first flower appearance which was followed by I_2 (IW/CPE=0.80). Whereas minimum number of node of first flower appearance was recorded with the irrigation level I_1 (IW/CPE=0.60).

Among the varieties, V_4 (Kashi Rajhans) registered maximum number of node of first flower appearance which was followed by $V_2>V_5>V_3$ in descending order. Minimum number of node of first flower appearance was recorded in case of variety V_1 (Arka Komal). Similar results hav been reported by Meena *et al.* (2018).

Among the interactions of irrigation levels and varieties non-significant variation was imposed on number of node of first flower appearance in french bean.

The irrigation levels had imposed significance influence on days to first flower appearance and days to 50 % flowering. The data obtained from trial revealed that irrigation level I_3 (IW/CPE=1.00) registered maximum days taken to first flower appearance and days to 50 % flowering which was followed by I_2 (IW/CPE=0.80). Whereas minimum days taken to first flower appearance and days to 50 % flowering was recorded with the irrigation level I_1 (IW/CPE=0.60). The lack of irrigation during the very dry and warm conditions experienced, reduced vegetative growth, canopy development, general plant development, and accelerated the rate of plant development to maturity in the unirrigated crops. This resulted in less days to flowering, podding and physiological maturity compared to the irrigated crops (Dapah *et al.* 1995). This observation is in agreement with the findings of *Al-Suhaibani et al.* (2009) and Gupta *et al*. (2017).

Among the varieties, V_4 (Kashi Rajhans) registered maximum days taken to first flower appearance and days to 50 % flowering which was followed by $V_2>V_5>V_3$, Minimum days taken to first flower appearance and days to 50 % flowering was recorded in case of variety V_1 (Arka Komal). The difference among varieties was attributed to their genetic makeup (Sharma et al., 2013). These findings are in agreement with the findings Santhi *et al*. (2015) and Sharma *et al*. (2015).

Combined effect of irrigation regimes and varieties had non significant influence on days taken to first flower appearance and days to 50 % flowering in french bean.

4.3 Yield parameters

Observations on number of pods per plant, number of seeds per pod, pod length (cm), shelling (%), seed yield per plant (g), seed yield (q/ha) and harvesting index (%) were recorded and presented as follows:

Irrigation levels exerted remarkable influence on number of pods per plant. Highest number of pods per plant was observed under the irrigation level I_3 (IW/CPE=1.00) which was followed by per plant in I_2 (IW/CPE=0.80). Lowest number of pods per plant was noted under the irrigation level I_1 (IW/CPE=0.60). Enhanced soil moisture increases nutrient uptake, photosynthesis and plant metabolic activities and thereby increases vegetative growth, number of flowers and fruits and ultimately increases number of pods per plant. These results are in accordance with the findings of El-Noemani et al. (2015), Gopail et al. (2015) and Saleh et al. (2018) in French bean.

Variety V_1 (Arka Komal) resulted in the highest number of pod per plant, which was followed by $V_3>V_5>V_2$ in descending order. Lowest number of pods per plant was found with the variety V_4 (Kashi Rajhans). This may be due to the genetic potential of these varieties. These findings are corroborated with those of Sharma *et al.* (2015), Meena *et al.* (2018) and Zeliang *et al*. (2018) in french bean.

Combined effect of irrigation regimes and varieties indicated significant effect on number of pods per plant in french bean.

Irrigation levels exerted remarkable influence on number of seeds per pod. Highest number of seeds per pod was observed under the irrigation level I_3 (IW/CPE=1.00) which was followed by per plant I_2. Lowest number of seeds per pod was noted under irrigation level I_1. Similar findings have been reported by Khan (2004).

The significant effect of varieties was showed on number of seed per pod. Variety V_1 (Arka Komal) resulted in the highest number of seeds per pod which was followed by $V_3>V_5>V_2$. Variety V_4 (Kashi Rajhans) recorded lowest number of seeds per pod. Such varietal differences are observed due to genetic makeup of the varieties (Maske *et al*., 2009). These findings are corroborated with those Ramana *et al.* (2011), Sharma *et al.* (2013) and Sharma *et al*. (2016).

Combined effect of irrigation regimes and varieties indicated non-significant effect on number of seeds per pod.

The pod length of french bean was significantly affected by irrigation levels. Maximum pod length was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2 (IW/CPE=0.80). Minimum pod length was recorded in case of irrigation level I_1 (IW/CPE=0.60). The high yield attributing characters was observed under I_3 may be due to the increased dry matter production might have resulted in greater synthesis of photosynthesis contributing to an increase in yield attributes. The beneficial effect of application of irrigation resulted in improved yield attributes was also be noticed by Kumar and Singh (2014), Gopal *et al*. (2015) and Honar (2017) in French bean.

Amongst varieties, longest pod (12.45 cm) was found under variety V_1 (Arka Komal) which was followed by variety V_3>V_5>V_2 with a pod length of in french bean. Smallest pod was observed in case of variety V_4 (Kashi Rajhans). These findings are corroborated with those reported by Santhi *et al.* (2015), Rahman *et al.* (2018) and Das *et al.* (2018) in French bean.

Combined effect of irrigation levels and varieties registered non-significant effect on pod length (cm) in french bean under the study.

The shelling (%) of french bean was significantly affected by irrigation levels. Maximum shelling (%) of was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2. Minimum shelling percent was recorded in case of irrigation level I_1 (IW/CPE=0.60).

Among the varieties, maximum shelling (%) was recorded in the variety V_1 (Arka Komal), which was followed by variety V_3>V_5>V_2 while the minimum shelling percent was found under variety V_4 (Kashi Rajhans). These findings could be attributed to the genotypic differences among varieties. This is in conformity with the findings of Maske *et al*. (2009) and Chadha *et al*. (2013).

Interactive effect of irrigation regimes and varieties exerted non significant influence on shelling (%).

Irrigation levels exerted remarkable influence on seed yield (g) per plant. Highest seed yield per plant was observed under the irrigation level I_3

(IW/CPE=1.00) which was followed by I_2 (IW/CPE=0.80). Lowest seed yield per plant was noted under irrigation level I_1 ((IW/CPE=0.60). Higher seed yield in treatment of 1.0 IW:CPE ratio may be due to higher value of yield attributing characters (Patel *et al.,* 2010).

Variety V_1 (Arka Komal) resulted highest seed yield per plant which was followed by $V_3>V_5>V_2$. Lowest seed yield per plant was found with the variety V_4 ( ). This finding is in accordance with Maske *et al.* (2009), Meena et al. (2018) and Sharma *et al*. (2016) in french bean.

Combined effect of irrigation regimes and varieties indicated non significant effect on seed yield (g) per plant.

The seed yield of french bean was significantly affected by irrigation levels. Maximum seed yield per hectare was recorded with irrigation level I_3 (IW/CPE=1.00) followed by I_2. Minimum seed yield per hectare was recorded in case of Irrigation level I_1 (IW/CPE=0.60). Interpretation of such findings was reported by (Hagab *et al*., 2014) who stated that adequate moisture availability in soil leads to increase various physiological processes, better nutrients uptake, higher rates of photosynthesis which might reflected on more number and area of leaves and higher yields. Similar results were observed by Patel *et al.* (2010), Singh *et al*. (2014) Gopal *et al*. (2015),

Among the varieties, maximum seed yield was recorded in the variety V_1 (Arka Komal), which was followed by variety $V_3>V_5>V_2$. While the minimum seed yield was recorded under variety V_4 (Kashi Rajhans). The difference in seed yield might be due to genetic potentiality of the varieties to utilize the growth resources and translocation photosynthesis from source to sink. Seed yield is a function of yield attributing characters; the significant seed yield resulted due to the increase in the yield attributes *viz.*, number of pods per plant, seed per plant and 100 seed weight (Maske *et al*., 2009). These results are in agreement to those reported by Sharma *et al*. (2013), Kumar and Singh (2014) and Meena *et al.* (2018) in French bean.

Interactive effect of irrigation regimes and varieties exerted non-significant influence on seed yield (q/ha). The maximum seed yield was recorded under I_3V_1 (IW/CPE=0.85+ Arka Komal) treatment combination, which was followed by I_2V_1. While the minimum seed yield was registered under the treatment combination I_1V_4 (IW/CPE=0.60+ Kashi Rajhans).

Significant influence of irrigation regimes was found on harvest index in french bean. Irrigation level I_3 revealed maximum harvest index followed by irrigation level I_2 (IW/CPE= 0.80). Whereas minimum harvest index was determined under the irrigation level I_1 (IW/CPE= 0.60). This is in conformity with the findings of Dapaah *et al*. (2000).

Varieties indicated significant variation for harvest index. Maximum harvest index was recorded under variety V_1 (Arka Komal). It was followed by $V_3>V_5>V_2$ in descending order. Variety V_4 (Kashi Rajhans) recorded minimum harvest index. These results are similar to those previously reported byMaske *et al.* (2009) and Uddin *et al.* (2017).

Combined effect of irrigation levels and varieties revealed non-significant influence on harvest index (%) in french bean.

4.4 Quality parameter

The quality parameters *viz*., crude protein, weight of 100 seed (g) and germination (%) in french bean seeds as influenced by irrigation levels and varieties and their interactions are presented as follows:

The results presented in Table 4.17 and illustrated in Fig.19 revealed significant effect of irrigation levels and varieties on crude protein in seeds of french bean.

Irrigation levels exhibited significant effect on crude protein seeds of french bean. Maximum crude protein in seeds was recorded under I_1 (IW/CPE=0.60). It was followed by irrigation level I_2 (IW/CPE=0.80) with the values of. Minimum crude protein was recorded under irrigation level I_3

(IW/CPE=1.00). These results are corroborated with the findings of Hegab et al. (2014) Saleh *et al*. (2018).

Significant effect of varieties was observed on crude protein in seeds of french bean. Among the varieties, V_1 (Arka Komal) observed the maximum protein content which was followed by $V_3>V_5>V_2$. Minimum protein content was recorded in case of variety V_4 (Kashi Rajhans). The results are also consensus with the findings of Ghanbari *et al.* (2013) and Meena *et al*. (2018) in french bean.

Combined effect of irrigation levels and varieties indicated non- significant effect on crude protein in seed of french bean.

Irrigation levels exhibited significant effect on weight of 100 seed (g) of french bean. Maximum weight of 100 seed was recorded under irrigation level I_3 (IW/CPE=1.00). It was followed by irrigation level I_2 with the values of. Minimum weight of 100 seed was recorded under irrigation level I_1 (IW/CPE=0.60). Similar results were found by Gopal et al. (2015) and Megawer et al. (2017).

Weight of 100 seed was significantly differed in french bean. Among the varieties, maximum weight of 100 seed was determined with the variety V_1 (Arka Komal) which was followed by $V_3>V_5>V_2$ in descending order. Minimum weight of 100 seed was recorded in case of variety V_4 (Kashi Rajhans). These findings are corroborated with those reported by Ramana et al. (2011) Uddin et al. (2017),

Combined effect of irrigation levels and varieties indicated non- significant effect on weight of 100 seed (g) of french bean.

Irrigation levels exhibited significant effect on germination (%) of french bean. Maximum germination was recorded under irrigation level I_3 (IW/CPE=1.00). It was followed by I_2 (IW/CPE=0.80) with th e values of. Minimum germination was recorded under irrigation level I_1 (IW/CPE=0.60). Similar results have been reported by Khan (2004).

Among the varieties, maximum germination was determined with variety V_1 (Arka Komal), which was followed by $V_3>V_5>V_2$. Variety V_4 (Kashi Rajhans)

found minimum germination. Similar finds have been reported by Sharma et al. (2014).

Combined effect of irrigation levels and varieties indicated non- significant effect on germination (%) of french bean.

4.5 Water utilization parameter

Irrigation levels exerted significant effect on water use efficience. Maximum water use efficiency was recorded under irrigation level I_1 (IW/CPE=0.60) followed by irrigation levels I_2 with the values of. While the minimum water use efficiency was registered under the irrigation level I_3 (IW/CPE=1.00). The probable reason might be due to irrigation scheduling (IW: CPE ratio) influenced the water status of the soil profile, evapotranspiration and water use efficiency. The results are corroborated with the findings of Gupta *et al*. (2017) Chaudhary *et al*. (2008) and Tyagi *et al.* (2012).

Among the varieties, maximum water use efficiency was recorded with variety V_1 (Arka Komal). It was followed by $V_3>V_5>V_2$ with WUE of, while minimum water use efficiency (5.63 kg/ha-mm) was found with variety V_4 (Kashi Rajhans). Similar results were found Tyel and Sabreen (2011) and Marzouk et al. (2016).

Combined effect of irrigation regimes and varieties exerted non-significant influence on water use efficiency (kg/ha-mm) in french bean.

4.6 Economics of different treatments for okra production

Irrigation levels exerted significant effect on gross income, net income and B:C ratio. Maximum gross income, net income and B:C ratio was recorded with of irrigation levels I_3 (IW/CPE=1.00) which was significantly higher over other irrigation levels. It was followed by irrigation levels I_2. While minimum gross income, net income and B:C ratio was recorded under irrigation level I_1 (IW/CPE=0.60). These results are in agreement with Gupta et al. (2017).

Highest gross income, net income and B:C ratio was recorded in variety V_1 (Arka Komal). It was followed by V_3, V_5 and V_2. Lowest gross income, net

income and B:C ratio was noted in variety V_4 (Kashi Rajhans). This might be due to higher yield associated with the respective cultivars (Zeliang *et al*., 2018).

Interactive effect of irrigation levels and varieties had exerted non-significant influence on gross income, net income and B:C ratio. But numerically highest gross income, net income and B:C ratio was realized in case of treatment combination I_3V_1, while lowest gross income, net income and B:C ratio was found under I_1V_4 treatment combination.

CHAPTER- VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

Chapter-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

An investigation entitled “Effect of varieties and irrigation regimes on growth, yield and quality of seed in french bean (*Phaseolus vulgaris* L.)” was conducted at Research Farm, College of Horticulture, Mandsaur during summer season 2018-19. Fifteen treatment combinations comprising of three irrigation levels (I1- IW/CPE=0.60, I2- IW/CPE=0.80, I3- IW/CPE=1.00) and five varieties (V1- Arka Komal, V2- Arka Arjun, V3- Arka Sharath, Kashi Rajhans and Kashi Sampann) were tested in split plot design with three replications. The findings obtained from the study have been summarized as follows:

6.1.1 Effect of irrigation levels

The results of the experiment with respect to growth parameters of french bean crop revealed significant effect of irrigation regimes on plant height, number of leaves, number of branches, fresh weight of shoot (g), dry weight of shoot (g), fresh weight of root (g), dry weight of root (g). Maximum plant height, number of leaves per plant, number of branches per plant, , fresh and dry weight of shoot and fresh and dry weight of root was recorded with irrigation level I_3(IW/CPE=1.00) at all stages under study. There was increase in all these traits with advancement of growth stage except number of branches, fresh and dry weight of plant under all the treatments.

Minimum number of node of first flower appearance was recorded under irrigation level I_1 (IW:CPE=0.600). Earliest days taken to first flower appearance and minimum days taken to 50 % flowering was observed under irrigation level I_1 (IW:CPE=0.600).

Yield attributing characters of french bean were studied with respect to number of pods per plant, number of seeds per plant, pod length (cm), shelling

(%), seed yield per plant (g), seed yield per hectare (q) and harvest index (%). Yield parameters in the french bean showed significant effect of irrigation levels. Highest number of pods/plant was recorded under the irrigation level I_3 (IW/CPE=1.00) followed by I2. Highest pod length (cm) and seed yield per hectare (q) was recorded under the irrigation level I_3 (IW/CPE=1.00) followed by I2. While the lowest value of all yield parameters was recorded under the irrigation level I_1(IW:CPE=0.600).

Quality parameters also revealed significant influence of irrigation regimes. Highest crude protein content was recorded under the irrigation level I_1(IW:CPE=0.600) followed by I_2. While lowest crude protein content was found under the irrigation level I_3 (IW/CPE=1.00). Highest weight of 100 seed (g) in french bean was recorded in irrigation regime I_3 (IW/CPE=1.00). Lowest weight of 100 seed (g) was found under the irrigation level I_1

Highest water use efficiency was observed with irrigation level I_1(IW:CPE=0.600).followed by I_2 while the lowest water use efficiency was registered with I_3 (IW/CPE=1.00).

Irrigation levels exerted significant effect on gross income, net income and B:C ratio. Maximum gross income, net income and B:C ratio was recorded with of irrigation levels I_3 (IW/CPE=1.00) which was significantly higher over other irrigation levels. It was followed by irrigation levels I_2. While minimum gross income, net income and B:C ratio was recorded under irrigation level I_1 (IW/CPE=0.60).

6.1.2 Effect of varieties

The findings of the experiment with respect to growth parameters revealed significant effect of varieties. Highest plant height, number of leaves, number of branches, fresh weight of shoot (g), dry weight of shoot (g), fresh weight of root (g), dry weight of root (g) was recorded with V_1 (Arka Komal) followed by V_3>V_5>V_2 in descending order, while minimum was recorded by variety V_4 (Kashi Rajhans).

Phenological parameters had influenced by varieties. Variety V_4 (Kashi Rajhans) registered maximum number of node of first flower appearance (5.52) which was followed by $V_2>V_5>V_3$ in descending order. Minimum number of node (4.12) of first flower appearance was recorded in case of variety V_1 (Arka Komal). Minimum days taken to first flower appearance and 50 % flowering were recorded in case of variety V_1 (Arka Komal).

Varieties had exerted significant influence on yield parameters. Highest number of pods per plant, number of seeds per plant, pod length (cm), shelling (%), seed yield per plant (g), seed yield per hectare (q) and harvest index (%). was recorded with the variety V_1 (Arka Komal) followed by $V_3>V_5>V_2$. Lowest was found with the variety V_4 (Kashi Rajhans).

Quality parameters of the cowpea indicated significant effect of varieties. Highest crude protein content, weight of 100 seed (g) and germination % in french bean was recorded under Variety V_1 (Arka Komal) followed by $V_3>V_5>V_2$. Minimum was recorded in case of variety V_4 (Kashi Rajhans).

Maximum water use efficiency was recorded with variety V_1 (Arka Komal). It was followed by $V_3>V_5>V_2$ with WUE of 7.31, 7.00 and 6.46 kg/ha-mm, while minimum water use efficiency (5.63 kg/ha-mm) was found with variety V_4 (Kashi Rajhans).

Highest gross income, net income and B:C ratio was recorded in variety V_1 (Arka Komal). It was followed by V_3, V_5 and V_2. Lowest gross income, net income and B:C ratio was noted in variety V_4 (Kashi Rajhans).

6.1.3 Combined effect of irrigation levels and varieties

Combined effect of irrigation levels and varieties showed non- significant influence on all growth, yield as well as quality parameters under the study.

Water use efficiency revealed significant influence of combined effect of irrigation regimes and varieties. Highest water use efficiency was observed with treatment combination I_3V_1 followed by I_2V_1

6.2 Conclusions

On the basis of present experiment, it may be concluded that among the irrigation levels, application of I_3 (IW/CPE=1.00) recorded significantly higher growth attributes, yield parameters and pod yield as well as 100 seed weight and germination %. Protein content in fresh pods was highest with I_1 irrigation level and lowest under I_3 irrigation regime. Highest water use efficiency was determined with I_1 irrigation level. Among the varieties, V_1 (Arka Komal) showed superiority for growth, yield and quality parameters followed by V_3 and V_5. Highest gross income, net income and B:C ratio was realized in case of treatment combination I_3V_1.

6.3 Suggestions for further work

- The experiment may be repeated for two or three years for confirmation of the results
- In the repeated experiment more levels of irrigation and varieties should be tested
- In the future studies more observations like quality parameters like carbohydrates content, total sugar content, total starch content should be tested

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APPENDICES

APPENDICES

Appendix – I. Analysis of variance of the plant height (cm) at different growth stages

Source of variation	Degree of freedom	Mean sum of square		
		Plant height		
		30	45	60
Replication	2	0.88	1.27	1.73
Irrigation levels (I)	2	52.35	17.65	169.28
Error A	4	**1.48**	**2.41**	**17.10**
Varieties (V)	4	74.07	57.43	71.61
Interaction (I x V)	8	0.77	5.54	2.87
Error B	24	**1.84**	**3.66**	**8.61**
CV		**7.77**	**7.28**	**8.37**

Appendix – II. Analysis of variance of the number of leaves per plant at different growth stage

Source of variation	Degree of freedom	Mean sum of square		
		Number of leaves		
		30	45	60
Replication	2	0.62	4.25	0.68
Irrigation levels (I)	2	115.99	134.26	232.18
Error A	4	**2.82**	**6.83**	**2.05**
Varieties (V)	4	22.29	47.41	37.41
Interaction (I x V)	8	1.83	1.46	4.33
Error B	24	**1.11**	**5.54**	**10.74**
CV		**8.59**	**9.03**	**9.45**

Appendix – III. Analysis of variance of the number of branches per plant at different growth stage

Source of variation	Degree of freedom	Mean sum of square		
		Number of branch		
		30	45	60
Replication	2	0.28	0.25	0.05
Irrigation levels (I)	2	11.27	13.79	11.13
Error A	4	**0.36**	**0.14**	**0.76**
Varieties (V)	4	6.02	14.48	15.96
Interaction (I x V)	8	0.35	0.90	0.91
Error B	24	**0.17**	**0.54**	**0.57**
CV		**11.61**	**10.19**	**9.29**

Appendix – IV. Analysis of variance of the fresh weight shoot and dry weight shoot (g) at harvest stages

Source of variation	Degree of freedom	Mean sum of square	
		Fresh weight shoot (g)	Dry weight shoot (g)
Replication	2	6.30	1.21
Irrigation levels (I)	2	46.17	73.46
Error A	4	**6.48**	**0.53**
Varieties (V)	4	30.18	30.92
Interaction (I x V)	8	4.10	0.90
Error B	24	**9.05**	**0.58**
CV	44	**8.14**	**8.76**

Appendix – V. Analysis of variance of the fresh weight root and dry weight root (g) at harvest stages

Source of variation	Degree of freedom	Mean sum of square	
		Fresh weight root (g)	Dry weight root (g)
Replication	2	0.03	0.01
Irrigation levels (I)	2	15.04	8.48
Error A	4	**0.72**	**0.07**
Varieties (V)	4	10.71	0.58
Interaction (I x V)	8	1.02	0.12
Error B	24	**0.47**	**0.05**
CV		**12.16**	**12.61**

Appendix – VI. Analysis of variance of the number of nod of first flower appearance at different growth stage

Source of variation	Degree of freedom	Mean sum of square
		Number of nod of first flower appearance
Replication	2	0.02
Irrigation levels (I)	2	15.57
Error A	4	**0.09**
Varieties (V)	4	3.00
Interaction (I x V)	8	0.07
Error B	24	**0.07**
CV		**5.83**

Appendix – VII. Analysis of variance of the days taken to first flower appearance and days taken to 50% flowering at different growth stage

Source of variation	Degree of freedom	Mean sum of square	
		Days taken to first flower appearance	Days taken to 50% flowering
Replication	2	0.18	0.41
Irrigation levels (I)	2	88.10	34.63
Error A	4	**7.48**	**0.42**
Varieties (V)	4	64.89	24.77
Interaction (I x V)	8	1.42	8.02
Error B	24	**7.94**	**7.46**
CV		**7.48**	**5.71**

Appendix –VIII. Analysis of variance of the number of pods per plant and number of seeds per pod at harvest stages

Source of variation	Degree of freedom	Mean sum of square	
		Number of pods per plant	Number of seeds per pod
Replication	2	1.16	1.30
Irrigation levels (I)	2	54.37	8.19
Error A	4	**1.16**	**0.32**
Varieties (V)	4	27.16	0.81
Interaction (I x V)	8	4.60	0.28
Error B	24	**2.57**	**0.24**
CV		**12.11**	**9.34**

Appendix – IX. Analysis of variance of the pod length (cm) and shelling% at harvest stages

Source of variation	Degree of freedom	Mean sum of square	
		Pod length (cm)	Shelling (%)
Replication	2	0.06	2.16
Irrigation levels (I)	2	17.35	89.92
Error A	4	**1.10**	**8.94**
Varieties (V)	4	8.85	54.55
Interaction (I x V)	8	0.74	3.82
Error B	24	**0.93**	**17.16**
CV		**8.57**	**5.94**

Appendix –X. Analysis of variance of the seed yield per plant (g) and seed yield per plant (g) under different treatments.

Source of variation	Degree of freedom	Mean sum of square	
		Seed yield per plant (g)	Seed yield per hectare (g)
Replication	2	23.47	51.52
Irrigation levels (I)	2	117.43	257.74
Error A	4	**7.80**	**17.12**
Varieties (V)	4	33.21	72.90
Interaction (I x V)	8	0.70	1.54
Error B	24	**2.38**	**5.22**
CV		**10.72**	**10.72**

Appendix – XI. Analysis of variance of the harvest index % and crude protein under different treatments.

Source of variation	Degree of freedom	Mean sum of square	
		Harvest index (%)	Crude protein (%)
Replication	2	3.83	19.71
Irrigation levels (I)	2	44.33	28.95
Error A	4	**2.58**	**3.84**
Varieties (V)	4	34.18	48.88
Interaction (I x V)	8	1.65	1.06
Error B	24	**1.78**	**1.96**
CV		**5.57**	**6.51**

Appendix – XII. Analysis of variance of the weight of 100 seed (g) and germination (%) under different treatments

Source of variation	Degree of freedom	Mean sum of square	
		Weight of 100 seed (g)	Germination (%)
Replication	2	9.79	11.91
Irrigation levels (I)	2	52.51	162.56
Error A	4	**2.54**	**14.07**
Varieties (V)	4	108.62	83.64
Interaction (I x V)	8	0.74	2.34
Error B	24	**2.97**	**21.41**
Total	44	**6.05**	**5.34**

Appendix – XIII. Analysis of variance of the water use efficiency (kg/ha-mm) under different treatments

Source of variation	Degree of freedom	Mean sum of square
		Water use efficiency
Replication	2	5.26
Irrigation levels (I)	2	1.60
Error A	4	**1.31**
Varieties (V)	4	8.59
Interaction (I x V)	8	0.53
Error B	24	**0.64**
CV		**11.58**

APPENDIX – XIV: Analysis of variance of the net income (Rs) & B:C ratio of french bean

Source of variation	D.F.	Mean sum of square		
		Gross income (Rs/ha)	Net income (Rs)	B:C Ratio
Replication	2	2898048210.92	2898048210.92	1.70
Irrigation levels (I)	2	14498110527.30	13126860711.33	5.73
Error A	4	962890732.84	962890732.84	0.54
Varieties (V)	4	4100566529.03	4100566529.03	2.46
Interaction (I x V)	8	86667332.19	86667332.19	0.06
Error B	24	293856309.82	293856309.82	0.18
CV		10.72	14.42	14.58

Appendix – XV. CPE and other meteorological data recorded during experiment (02/10/18-12/02/19) on daily basis

Date	Temperature ^{o}C		Rainfall (mm)	RH (%)	CPE (mm)
	Min.	Max.			
02/10/2018	34.3	21.5	-	68	4.3
03/10/2018	34.5	21.5	-	65	4.2
04/10/2018	34.3	20.5	-	61	4.2
05/10/2018	34.2	20.8	-	63	4.1
06/10/2018	34.4	20.7	-	65	3.6
07/10/2018	33.5	20.5	-	61	4.9
08/10/2018	33.7	20.8	-	61	5.1
09/10/2018	34.2	20.6	-	63	4.8
10/10/2018	35.2	21.3	-	63	3.9
11/10/2018	36.1	21.6	-	64	5.4
12/10/2018	36.4	20.3	-	65	4.5
13/10/2018	35.4	21.3	-	61	5.1
14/10/2018	36.2	21.4	-	66	5.8
15/10/2018	34.0	20.5	-	63	5.3
16/10/2018	34.0	21.2	-	61	5.2
17/10/2018	34.1	21.4	-	60	5.5
18/10/2018	34.2	21.0	-	56	5.6
19/10/2018	35.3	20.8	-	55	5.8
20/10/2018	33.0	20.5	-	53	5.5
21/10/2018	35.0	20.4	-	45	5.6
22/10/2018	35.2	18.6	-	42	5.4
23/10/2018	34.3	18.6	-	44	5.8
24/10/2018	34.3	18.3	-	61	3.8
25/10/2018	34.2	18.2	-	63	4.8
26/10/2018	38.3	18.2	-	66	4.5
27/10/2018	34.2	17.8	-	62	4.7
28/10/2018	33.2	17.5	-	64	4.2
29/10/2018	34.3	17.3	-	55	4.5
30/10/2018	34.1	17.6	-	49	4.7
31/10/2018	33.2	16.4	-	45	4.9
01/11/2018	33.3	16.4	-	44	4.9
02/11/2018	32.4	16.6	-	41	4.7
03/11/2018	33.1	16.9	-	41	4.0
04/11/2018	33.1	15.9	-	44	3.8
05/11/2018	33.3	17.8	-	60	3.6
06/11/2018	32.7	17.9	-	65	3.7
07/11/2018	30.8	17.2	-	62	3.8
08/11/2018	30.2	15.8	-	56	3.8
09/11/2018	30.5	15.8	-	57	3.6
10/11/2018	30.2	14.9	-	57	3.6

11/11/2018	29.5	14.8	-	60	3.6
12/11/2018	30.5	13.3	-	50	3.5
13/11/2018	30.6	13.5	-	60	3.6
14/11/2018	30.7	13.1	-	62	3.4
15/11/2018	33.3	16.3	-	62	3.2
16/11/2018	33.4	16.0	-	42	3.0
17/11/2018	35.2	15.7	-	53	3.1
18/11/2018	32.3	14.3	-	59	2.9
19/11/2018	31.7	14.8	-	62	3.0
20/11/2018	32.9	15.0	-	52	3.1
21/11/2018	32.9	15.9	-	52	3.0
22/11/2018	32.1	14.3	-	50	2.9
23/11/2018	32.1	14.3	-	54	3.0
24/11/2018	30.3	15.3	-	65	2.9
25/11/2018	32.5	15.2	-	69	2.9
26/11/2018	31.6	14.4	-	65	2.7
27/11/2018	31.8	14.0	-	60	2.7
28/11/2018	31.9	14.0	-	67	2.6
29/11/2018	28.1	13.4	-	65	2.6
30/11/2018	28.2	12.7	-	61	2.5
01/12/2018	29.3	12.2	-	72	2.0
02/12/2018	29.2	12.4	-	75	1.9
03/12/2018	28.9	12.5	-	77	1.9
04/12/2018	28.5	11.5	-	81	1.9
05/12/2018	27.6	11.5	-	84	2.0
06/12/2018	27.5	12.1	-	83	1.8
07/12/2018	28.3	12.9	-	81	1.8
08/12/2018	28.1	11.5	-	69	1.9
09/12/2018	27.9	11.7	-	70	1.8
10/12/2018	26.8	11.3	-	69	1.9
11/12/2018	27.1	12.2	-	65	1.8
12/12/2018	27.6	12.5	-	65	1.8
13/12/2018	27.4	12.4	-	62	1.7
14/12/2018	26.4	12.2	-	60	1.9
15/12/2018	24.2	10.2	-	72	1.9
16/12/2018	24.4	10.1	-	75	1.8
17/12/2018	32.1	9.8	-	77	1.8
18/12/2018	23.0	8.3	-	74	1.7
19/12/2018	22.8	8.0	-	72	1.7
20/12/2018	24.2	8.2	-	70	1.8
21/12/2018	24.2	8.1	-	70	1.8
22/12/2018	25.3	9.2	-	72	1.7
23/12/2018	25.2	9.4	-	71	1.6
24/12/2018	27.0	10.4	-	71	1.6
25/12/2018	27.5	10.2	-	68	1.7

26/12/2018	27.4	9.5	-	71	1.6
27/12/2018	26.2	8.7	-	75	1.6
28/12/2018	25.8	8.5	-	71	1.5
29/12/2018	25.5	8.4	-	70	1.7
30/12/2018	24.4	7.5	-	62	1.7
31/12/2018	23.5	5.3	-	59	1.5
01/01/2019	23.0	5.2	-	63	1.5
02/01/2019	23.2	5.0	-	61	1.5
03/01/2019	26.4	7.7	-	60	1.5
04/01/2019	25.5	7.6	-	97	1.6
05/01/2019	25.2	8.8	-	95	1.7
06/01/2019	26.2	7.0	-	59	1.7
07/01/2019	26.3	7.5	-	60	1.7
08/01/2019	25.2	7.6	-	75	1.6
09/01/2019	24.5	8.5	-	71	1.6
10/01/2019	26.5	9.0	-	76	1.8
11/01/2019	26.5	9.0	-	77	1.8
12/01/2019	27.7	9.3	-	75	1.9
13/01/2019	28.1	10.1	-	76	1.9
14/01/2019	26.2	9.4	-	69	1.9
15/01/2019	25.6	8.4	-	65	2.0
16/01/2019	25.0	7.0	-	63	1.9
17/01/2019	26.0	8.5	-	75	1.9
18/01/2019	26.2	8.5	-	72	1.9
19/01/2019	26.1	8.4	-	70	1.9
20/01/2019	26.0	8.4	-	68	2.0
21/01/2019	26.0	8.6	-	70	2.0
22/01/2019	27.0	10.5	-	62	1.8
23/01/2019	28.0	10.4	-	68	1.8
24/01/2019	28.9	10.0	-	70	1.8
25/01/2019	24.7	8.0	-	70	1.9
26/01/2019	24.0	7.0	-	75	1.9
27/01/2019	23.0	7.0	-	71	1.9
28/01/2019	23.0	7.4	-	68	1.9
29/01/2019	22.5	7.5	-	65	2.0
30/01/2019	22.0	8.0	-	66	2.1
31/01/2019	23.5	8.0	-	66	2.1
01/02/2019	24.0	8.5	-	60	2.1
02/02/2019	24.0	9.0	-	65	2.2
03/02/2019	25.0	9.8	-	66	2.2
04/02/2019	28.5	11.0	-	69	2.2
05/02/2019	28.7	12.0	-	72	2.2
06/02/2019	29.0	12.0	-	75	2.3
07/02/2019	30.0	13.4	-	70	2.3
08/02/2019	28.0	11.0	-	70	2.3

09/02/2019	27.0	10.0	-	68	2.3
10/02/2019	28.0	10.0	-	69	2.4
11/02/2019	25.4	10.4	-	67	2.4
12/02/2019	25.8	10.9	-	60	2.5

Appendix XVI: Fixed cost of French bean seed production excluding the cost of the treatment inputs (Rs./ha)

No. S.	**Material/operation**	**Cost (Rs.)**
1.	Land preparation	2500
2.	Seed	10500
3.	Sowing	3000
4.	Seed treatment	200
5.	Urea (130.43 kg)	771
6.	DAP (173.91 kg)	4869
7.	MOP (133.33 kg)	2520
8.	Weeding	3000
9.	Plant protection	5000
10.	Harvesting	3000
11.	Total	35360

Appendix XVII: Treatment cost per hectare

Sr. No.	Irrigation levels	Number of irrigations	Cost per irrigation (Rs./ha)	Total cost (Rs./ha)
1.	I_1 –IW/CPE = 0.60	4	1000	4000
2.	I_2 –IW/CPE = 0.80	6	1000	6000
3.	I_3 –IW/CPE = 1.00	7	1000	7000

Appendix – XVIII: Economics of different treatments

Treatment combination	Common Expenditure (Rs.)	Treatment cost (Rs.)	Total cost of cultivation (Rs./ha)	Yield (q/ha)	Gross income* (Rs.)	Net income (Rs.)	C:B Ratio
I_1V_1	35360	4000	39360	21.20	159036.88	119676.88	3.04
I_1V_2	35360	4000	39360	15.79	118460.75	79100.75	2.01
I_1V_3	35360	4000	39360	18.78	140851.71	101491.71	2.58
I_1V_4	35360	4000	39360	12.62	94666.57	55306.57	1.41
I_1V_5	35360	4000	39360	17.13	128481.35	89121.35	2.26
I_2V_1	35360	6000	41360	25.85	193851.66	152491.66	3.69
I_2V_2	35360	6000	41360	19.82	148629.48	107269.48	2.59
I_2V_3	35360	6000	41360	22.69	170147.98	128787.98	3.11
I_2V_4	35360	6000	41360	17.33	129999.87	88639.87	2.14
I_2V_5	35360	6000	41360	21.61	162073.91	120713.91	2.92
I_3V_1	35360	7000	42360	28.69	215184.97	172824.97	4.08
I_3V_2	35360	7000	42360	24.20	181481.30	139121.30	3.28
I_3V_3	35360	7000	42360	25.49	191147.96	148787.96	3.51
I_3V_4	35360	7000	42360	22.77	170777.61	128417.61	3.03
I_3V_5	35360	7000	42360	25.82	193666.47	151306.47	3.57

* Sale price of produced: Rs. 75/kg

VITA

The author of the thesis Shivraj Bairwa S/o Shree Ramcharan Bairwa was born on June 3, 1990 at Vill.- Adotpura (Rajpura), P.O.- Adotpura, Teh. – Baroda, Distt.- Sheopur, Madhya Pradesh. He passed High School Certificate Examination in the year 2007 with 60.2 % and Higher Secondary School Certificate Examination in 2009 with 55 % marks from the M.P. Board.

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He was allotted an interesting research problem entitled “Effect of varieties and Irrigation regimes on growth, yield and quality of seed in french bean {*Phaseolus vulgaris* (L.)}” of his choice for thesis work, which has been completed by him and presented in the form of this thesis.

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