EFFECT OF NUTRIENT SOURCES AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF FRENCH BEAN

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DHAKA -1207

DECEMBER, 2017

EFFECT OF NUTRIENT SOURCES AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF FRENCH BEAN

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A Thesis
Submitted to the Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JULY-DECEMBER, 2017

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*This is to certify that thesis entitled, "**EFFECT OF NUTRIENT SOURCES AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF FRENCH BEAN (Phaseolus vulgaris L.)**" submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **SANGITA MISTRY**, Registration No. **16-07533** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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ACKNOWLEDGEMENTS

The author seems it a much privilege to express her enormous sense of gratitude to the Almighty God who enables her to complete the research work successfully and prepare this thesis for the degree of Master of Science (M.S.) in Horticulture.

The author feels proud to express her deep sense of gratitude, sincere appreciation and immense indebtedness to her supervisor **Prof. Dr. Md. Ismail Hossain**, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor **Dr. Jasim Uddain**, Associate Professor, Department of Horticulture, SAU, Dhaka, for his scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.

It is also an enormous pleasure for her to express her cordial appreciation and thanks to all respected teachers of the Department of Horticulture, Sher-e-Bangla Agricultural University, for their encouragement and co-operation in various stages towards completion of this research work.

The author deeply acknowledges the profound dedication to her beloved Father, Mother and Brother for their moral support, steadfast encouragement and continuous prayer in all phases of academic pursuit from the beginning to the completion of study successfully.

Finally, the author is deeply indebted to her friends and well-wishers specially her beloved husband Pranta Das and Sonika Khan Sithi for their kind help, constant inspiration, co-operation and moral support which can never be forgotten.

The Author

EFFECT OF NUTRIENT SOURCES AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF FRENCH BEAN

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ABSTRACT

A field experiment was carried out in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period of November 2016 to March 2017 The variety BARI Jhar Sheem 1 was used as test crop. Four levels of nutrient sources *viz*. F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 t ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1}) and three levels of irrigation frequency *viz*. I_1 = 3 days interval, I_2 = 6 days interval and I_3 = 9 days interval were used for the present study. The experiment was laid out in Randomized Complete Block Design with three replications. Different nutrient sources treatment showed significant influence on most of the parameters and the treatment. The highest yield ha^{-1} (12.87 t) of French bean was obtained from F_4 and the lowest (9.05 t) was obtained from F_1. Considering different irrigation frequency, the highest yield ha^{-1} (12.07 t) of French bean was observed in I_2 and the lowest (9.47 t) was obtained from I_3. In terms of combined effect of nutrient sources and irrigation frequency, all the studied parameters were influenced significantly. The highest pod yield ha^{-1} (15.19 t) was recorded from the treatment combination of F_4I_2 where the lowest (8.53 t) was recorded from the treatment combination of F_1I_3. Therefore, Application of N_{30}+P_{10}+K_{15} and Vermicompost (5 t ha^{-1}) with Irrigation at 6 days interval was best for French bean production.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization of the United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is an important leguminous short duration vegetable crop, highly proteinaceous in nature (Ahlawat and Sharma, 1989). It is an important legume vegetable belonging to the family *Leguminosae* and sub family *Papilionaceae* which is a native of Central and South America (Swiader *et al*., 1992). It is also named as bush bean, kidney bean, snap bean, pinto bean, green bean, raj bean, common bean, basic bean, harcot bean, navy bean, pole bean, wax bean, string bean and bonchi (Salunkhe *et al.*, 1987). French bean (*Phaseolus vulgaris* L.) is commonly known as 'Forashisheem' or 'Jharsheem' in Bengali (Roy *et al*., 2006). It is a dual purpose crop grown as pulse and also consumed as immature tender fruits. It is an important legume, grown in the areas of Jessore, Rangpur, Comilla, Chittagong and Sylhet in Bangladesh.

It is an annual herbaceous plant and widely cultivated throughout the temperate, tropical and sub-tropical areas of the world (George *et al.*, 1985). But it is more compatible as a winter (rabi) crop in the northern eastern plain of India (AICPIP, 1987). According to the FAO statistics, French bean including other related species of the genus *Phaseolus* took possession of 32.08 million hectares of the world cropped area and the yield of pods was about 23,139,004 tons (FAO, 2013).

Brazil is the major French bean producing country in the world. There is no statistics about the area and yield of this crop in Bangladesh. It is not a new crop in our country and is cultivated in Sylhet, Cox's Bazar, Chittagong Hill Tracts and some other parts of the country in a rather limited scale. At present, Hortex Foundation and BRAC are attempting to enhance the production area because French bean is now exportable vegetable among others.

Its edible immature pods comprise protein, carbohydrate, fat, fiber, thiamin, riboflavin, Ca and Fe (Shanmugavelu *et al*., 1989) and the seed supplies significant amount of thiamin, niacin, folic acid as well as fiber (Rashid, 1999).

Production of French bean depends on many factors such as quality of seed, time of sowing, irrigation schedule, fertilizer and proper management practices. Among those factors, fertilizer management is an important factor to get high yield. Organic manure such as vermicompost is an eco-friendly, cost effective and ecologically sound bio-fertilizer. Use of vermicompost has a significant positive influence on seed germination and seedling vigor, plant growth, flowering, fruiting, tuberization, root development, color, shelf-life and quality of vegetables (Premsekhar & Rajashree, 2009). French bean responds considerably to major essential elements like N, P and K in respect to its growth and yield (Thompson and kelly, 1957). Nitrogen management plays a significant role in maximizing production of French bean. Nitrogen is essential for its vegetative growth and development. An optimum amount of nitrogen is required to obtain maximum yield and good quality French bean. Phosphorus deficiencies may reduce and stunted plant growth. A deficient in potassium shows deformed plant parts.

However, growth and high yield of French bean is also influenced by irrigation frequency. 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 (Boyer *et al*., 2011). Efficient use of water in any irrigation system is vital especially in arid and semi-arid regions. The lack of proper irrigation frequency causes drought condition. French bean plants (*Phaseolus vulgaris* L.) are important protein source world-wide. However, they are sensitive to drought conditions. Growth and productivity of bean plants are extremely affected by water stress (Millar and Gardner, 1972). Moreover, according to El-TohaMy *et al*. (1999), water stress resulted in a decline of leaf water potential, stomatal conductance, photosynthesis rate and all growth, productivity and quality parameters of the plants. It reduces plant growth by affecting photosynthesis, respiration, translocation, ion uptake, carbohydrates and nutrient metabolism and growth promoters (Farooq *et al*., 2009). Drought stress reduces leaf expansion (Alves and Setter, 2004), accelerates leaf senescence and leads to death of leaf tissue.

Research on the growth and yield of French bean influenced by fertilizer management and irrigation schedule is very limited. The yield of French bean may be increased through judicious combination of fertilizer management and irrigation schedule. Considering all above the factors, the present study was undertaken with the following objectives:

1. To determine the suitable nutrient sources practices for better growth and maximum yield of French bean;
2. To find out the optimum irrigation frequency on growth and yield of French bean; and
3. To investigate the appropriate combination of nutrient sources and irrigation frequency for obtaining higher yield of French bean.

CHAPTER II

REVIEW OF LITERATURE

French bean (*Phaseolus vulgaris* L.) is a popular, common and important Legume vegetable which is commercially cultivated in Bangladesh during Rabi season. Many research works have been done in different parts of the world on the growth and yield of French bean. But available literature regarding effect of nutrient sources and irrigation frequency is insufficient in Bangladesh. However, some of the literatures relevant to the effect of nutrient sources and irrigation frequency on French bean production are reviewed in this chapter.

2.1 Effect of nutrient sources:

El-Hassan *et al.* (2017) reported that treatments of compost and vermicompost individually or in combination with or without adding 50% of recommended dose of mineral fertilizers, were investigated on bean plants. The maximum height of 68.00 cm and 58.85 cm was obtained with 100% Mineral Fertilizer during 2016 and 2017 respectively, whereas it was 42 cm and 39.43 cm using 100% compost during 2016 and 2017 respectively and using 100% vermicompost it was 51.33 cm and 44.96 cm in 2016 and 2017 respectively.

Islam *et al*. (2016) carried out an experiment in the greenhouse of the Institute of Biological Sciences, Faculty of Science, University of Malaya, Kualalumpur Malaysia during September, 2013 to February 2014. They used Vermicompost (20%), Traditional Compost (20%) and N:P:K fertilizer (farmer’s practice) to determine the growth and yield attributes of bush bean (*Phaseolus vulgaris*), winged bean (*Psophocarpus tetragonolobus*) and yard long bean (*Vigna unguiculata*). For bush bean, total plant height was the highest 314.19 cm in VC (20%) treated plants and the lowest 160.24 cm in the FP. Bush bean grown with VC (20%) produced the highest number of pods 58.93 compared to 22.20 recorded in the FP treatment. For bush bean, regarding the length of the pod it was highest in VC (20%) treatment 10.76 cm followed by compost 9.87 cm and the shortest pod length were observed in FP treated plants with 7.89 cm. For bush bean, single pod weight was highest in the VC (20%) treatments compared to the FP treatment with the highest recorded values of 5.09 g and the lowest value observed were 3.76 g. Bush bean grown with VC (20%) had the highest pod yield of 2.98 t ha^{-1} followed by TC (20%) and FP (20%) which provided 1.45 t ha^{-1} and 0.83 t ha^{-1} of pods, respectively.

Sarma *et al*. (2014) conducted an experiment to study the effect of different combinations of organic sources of nutrients viz., vermicompost, FYM, rock phosphate along with bio-fertilizer on different growth parameters, yield and profitability of French bean cultivar Arka Anoop. In this investigation, the results revealed that application of vermicompost + FYM + Rhizobium + rock phosphate (T_2) provided the maximum plant height 37.50 cm (after 60 days of sowing) followed by 29.59 cm in T_3 (vermicompost + RP + Rhizobium) whereas minimum height was 19.50 cm in T_1 (absolute control). He studied that application of vermicompost + FYM + Rhizobium + rock phosphate (T_2) provided the maximum number of branches per plant (6.48 after 60 days of sowing) while the least number of branches 4.34 were observed in T_1 (control).In this investigation, the results revealed that in treatment T_2 (vermicompost + FYM + Rhizobium + rock phosphate) the yield per plant was maximum 300.05 g and it was minimum 221.12 g in T_1 (control). In this investigation, the results revealed that in treatment T_2 (vermicompost + FYM + Rhizobium + rock phosphate) the length of the pods were maximum 12.16 cm while in T_1 (control) the length of the pods were minimum 10.36 cm.

Thriveni *et al*. (2015) reported that 100 percent N:P:K + vermicompost + biofertilizers (Azotobacter, Azospirillum and phosphate solubilizing bacteria) had a beneficial effect on bitter gourd *viz*. maximum vine length (534 cm), number of branches per vine (18.0), maximum number of fruits per plant (40.0), fruit weight (86.4 g), fruit girth, fruit yield (4036 kg ha^{-1}), ascorbic acid (111.1 mg/100 g), TSS (2.10 °Brix) and protein content (1.76%).

Yourtchi *et al*. (2013) carried out a field experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato. Experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels (0, 4.5, 9, and 12 ton ha^{-1}). Results illustrated that the highest plant height, leaf and stem dry weight, Leaf Area Index (LAI), fresh and dry weight of tuber, total tuber weight, total number of tuber, tuber diameter, nitrogen percent of tuber, potassium percent of tuber and phosphorous percent of tuber were found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application at the rate of 12 ton ha^{-1} promoted all above traits except plant height in compared to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments. To gain highest yield and avoidance of environments pollution use of 150 kg N ha^{-1} nitrogen fertilizer and vermicompost application of 12 t ha^{-1} are suggested.

Singh *et al*. (2011) investigated the effects of vermicompost, NPK fertilizer and organic mulch on crop growth, nodulation and pod yield of French bean. The shoot length, number of primary branches, shoot fresh weight and shoot dry weight, pod fresh weight and pod dry weight were increased by 28-63% through application of $N:P_2O_5:K_2O$ @ 8:13:10 kg ha^{-1} + vermicompost 3.75 t ha^{-1}. Application of vermicompost reduced nodule fresh weight and nodule dry weight by 44.9 and 44.5%, respectively. This study shows that application of N: P_2O_5: K_2O fertilizer @ 8-15:13-25:10-20 kg ha^{-1}, vermicompost @ 2.50-3.75 t ha^{-1}, 4 cm thick mulch of dried crop residues and 50% irrigation is the most suitable and sustainable strategy to improve plant growth, pod formation, pod number, pod length, pod diameter and pod yield of French bean and soil health of mild-tropical climate during dry season.

Ansari and Kumar (2010) revealed that combination organic fertilizers vermicompost and vermiwash combination compared with control and chemical fertilizers had great influence on plant growth parameters. The average yield of okra *(A. esculentus*) during trial showed a significantly greater response in comparison with the control by 64.27%. Fruits were found to have a greater percentage of fats and protein content when compared with those grown with chemical fertilizers by 23.86 and 19.86%, respectively.

Thakur *et al.* (2010) conducted a field experiment to evaluate the effect of different organic manures and bio-fertilizers on French bean. The study revealed that among all the treatments, combined application of vermicompost and biofertilizers increased the growth and yield of the crop in comparison to control.

A field experiment was performed to determine the effects of cow manure and vermicompost on plant growth, metabolite contents and antioxidant activities of Chinese cabbage were investigated in pot cultures. Five treatments were designed by mixing vermicompost and soil at ratio of 0:7, 1:7, 2:7, 4:7 and 7:0 (w/w). Marketable weight of Chinese cabbage was significantly ($p<0.05$) higher in the 2:1 treatment than in the other treatments, while plants grown in the full soil treatment (0:7) showed the lowest marketable weight. Vermicompost application significantly increased the nutrient content of Chinese cabbage leaves ($p<0.05$), especially in the 4:7 treatment, with increases in the contents of soluble sugar, soluble protein, vitamin C, total phenols and total flavonoids by 62, 18, 200, 25 and 17% compared to the full soil treatment, respectively (Wang *et al*., 2010).

Singh *et al*. (2009) conducted an investigation at field research center of Department of Seed Science and Technology, H.N.B. Garhwal University, Srinagar (India), during Rabi season, 2007 to explore the effect of organic sources of nutrients viz., vermicompost, FYM and along with inorganic fertilizers in French bean under irrigated condition with an objective to study growth and yield without degrading soil quality by using various nutrient compositions. In this investigation, vermicompost treatment (T_2) recorded the maximum height 30.13 cm of the French bean while minimum height growth of 21.09 cm was observed in N:P:K + Vermicompost (VC) + FYM (T_6). In this investigation, highest number of flowers per plant 36.4, pods per plant 25.2, pod length 10.8 cm and single pod weight 12 g were obtained from vermicompost treatment (T_2) while the least values were observed in control (T_7).

A field experiment was conducted in 2005-06 in Mashhad, Iran, to investigate the effects of organic amendments, synthetic fertilizers and compost extracts on crop health, productivity and storability of tomato. The treatments included different fertilizers of cattle, sheep and poultry manures, green-waste and household composts and chemical fertilizers of urea and superphosphate and five aqueous extracts from cattle manure, poultry manures, green-waste and household composts plus water as control. The results revealed that the application of poultry manure showed lower disease incidence, as shown by 80% healthy tomato, compared with the other fertilizers. However, the organic fertilizers used did not give higher yields compared with chemical fertilizers. Sheep manure and chemical fertilizers led to the highest total yield of tomato. Marketable yield was highest in poultry manures of 16 t ha^{-1} and lowest in chemical fertilizer of 7 t ha^{-1}, 6 weeks after storage. The effects of aqueous extracts were not significant on either crop health or tomato yield and the results were inconsistent. The compost made of poultry manure, therefore, appears to be a promising ecological alternative to classical fertilizers (Ghorbani *et al*., 2008).

Ullah *et al*. (2008) carried out a field experiment at the Horticultural Farm of Bangladesh Agricultural University (BAU), Mymensingh during the period from December 2004 to April 2005 to study the effect of organic manures and fertilizers on the yield of Brinjal. There were five treatments consisting of organic, inorganic and combined sources of nutrient, of which the combined treatment (60% organic + 40% inorganic) showed the best performances. The maximum branching (20.1) with the highest number fruits plant-1 (15.2), fruit length (14.1 cm), fruit diameter (4.3 cm) and single fruit weight (52.4 g) were found combined application of organic and inorganic sources of nutrients. Application of mustard oil cake or vermicompost or poultry manure alone gave better performance compared to only chemical fertilizers. The organic matter content and availability of N, P, K and S in soil were increased by organic matter application.

Alam *et al*. (2007) performed an experiment to investigate the effect of vermicompost and NPKS fertilizers on growth and yield of potato (cv. Cardinal) in Level Barind Tract (AEZ-25) soils of Bangladesh. The organic matter of the experimental field soil was very low and in case of N, P, K and S also low. Application of vermicompost and NPKS significantly influenced the growth and yield of potato. The treatment, Vermicompost 10 t ha^{-1}+100% NPKS (doses of NPKS were 90, 40, 100, 18 kg ha^{-1} for potato) produced the highest (25.56 t ha^{-1}) tuber yield of potato. The lowest yield and yield contributing parameters recorded in control. Application of various amounts of vermicompost (2.5, 5, 10 t ha^{-1}) with NPKS fertilizers (50% and 100%) increased the vegetative growth and yield potato. Vermicompost at 2.5, 5 and 10 t ha^{-1} with 50% of NPKS increased tuber yield over control by 78.3, 96.9 and 119.5 t ha^{-1} respectively. And vermicompost at 2.5, 5 and 10 t ha^{-1} with 100% of NPKS increased tuber yield by 146.8, 163.1 and 197.9 %, respectively. The results indicated that vermicompost (10 t ha^{-1}) with NPKS (100%) produced the highest growth and yield of potato.

The vermicompost applications increased plant heights and yields of peppers significantly including increased leaf areas, plant shoot biomass and marketable fruit weights (Arancon *et al*., 2005)

Uddin *et al*. (2004) accomplished two-years field experiment at the Regional Agricultural Research Station, BARI, Hathazari, Bangladesh, in the year 2001-02 on the fertilizer requirement of carrot as influenced by different levels of NPKS (N: P: K: S at 120: 45: 120: 30, 90: 30: 60: 20 and 60: 15: 30: 10 kg ha^{-1})

and cowdung (0 and 5 t ha-1) were used in the investigation. Different combinations of NPKS and cowdung showed significant influence on the yield of carrot. The combination of fertilizer 120: 45: 120: 30 kg ha^{-1} of NPKS and 5 t cowdung ha^{-1} produced root yield of 27.22 t ha^{-1} which was 303% higher than control treatment.

Kumar *et al*. (2004) found that increment in NPK level (0:0:0 to 120:60:45 kg ha^{-1}) significantly increased plant height from 17 to 21.18 cm. He observed that number of pods per plant, pod length and pod diameter significantly increased due to application of fertilizers at the rate of 120:60:45 kg N: P_2O_5: K_2O ha^{-1} over control and 40:20:15 kg N: P_2O_5: K_2O ha^{-1}.

Saxena *et al*. (2003) conducted a research in Kanpur, Uttar Prades, India during the Rabi season of 2000-2002 where PDR-14 were supplied with 0, 60 and 120 kg N and K ha^{-1} and 0, 60 and 90 kg P ha^{-1} on French bean (*Phaseolus vulgaris* cv.) . Leaf area index, leaf area distribution and relative growth rate increased with growth stages and increasing rated of N, P and K. Crop yield increased with increasing rates N and P during both years.

In an experiment with French bean, Yadav and Vijayakumari (2003) found that the maximum overall growth and yield recorded from the vermicompost treatment and admixed with FYM were found consistent with the findings.

Vishwakarma *et al*. (2002) conducted a field experiment in Varanasi, Uttar Pradesh, India, during 1996-97 and 1997-98 to evaluate the response of two French bean (*Phaseolus vulgaris)* cultivars (Holland 84 and PDR 14) to different application rates (0, 30, 60, 90 kg ha^{-1}) of nitrogen. Holland 84 was the tallest, whereas PDR 14 recorded the highest dry matter production per plant as well as pods per plant, grains per pod, grains per plant, pod length and 100-grain weight. The growth, yield attributes and yield increased with increasing rates of nitrogen up to 90 kg ha^{-1}.

Chaudhuri *et al.* (2001) observed the nutrient management in French bean in Nagpur, Maharashtra, India. They recommended dose of 90 kg N ha^{-1} and 60 P_2O_5 ha^{-1}.

Dhanjal *et al*. (2001) reported that the plant height of French bean increased from 22.69 cm to 27.13 cm during 1996-97 and 21.69 cm to 26.45 cm during 1997-98, by increased nitrogen fertilization from 0-120 kg N ha^{-1}. He observed that linear increase in the number of branches per plant up to 120 kg N ha^{-1}, with HUR-87 variety of French bean on sandy loam soil and significantly higher number of pods per plant was recorded in the treatment receiving 120 kg N ha^{-1}.

Rana *et al.* (2001) opined that plant height of Rajmash cultivar Kailash increased significantly with increased fertility up to N_{40} P_{80} K_{20} kg ha^{-1}. He reported that all fertility levels tried (N_{20} P_{60} K_{00}, N_{20} P_{60} K_{20}, N_{20} P_{80} K_{20}, N_{40} P_{60} K_{20} and N_{40} P_{80} K_{20}) increased number of pods per plant significantly over farmers practice (N_{15} P_{15} K_{15}).

Rajesh *et al*. (2001) accomplished an experiment in India to study the effect of N (80, 160 and 240 Kg ha^{-1}) and S (0, 20, 40 and 60 Kg ha^{-1}) on the nutrient uptake and grain yield of French bean (*Phaseolus vulgaris* cv.; Hur 137). The highest seed yield was found at N level of 240 kg ha^{-1} (2091kg ha^{-1}) and S (6.58 kg ha^{-1}) and that of straw yields (3331 kg ha^{-1}) and highest to total N (90.70 kg ha^{-1}) and S (6.58 kg ha^{-1}) uptake. Sulphur at 40 kg ha^{-1} recorded the highest seed yield (1811 kg ha^{-1}) and highest total N (77.45 kg ha^{-1}) and S (6.06 kg ha^{-1}) uptake.

Chavan *et al.* (2000) conducted a field experiment in Maharashtra, India during the Rabi season of 1990 where French bean (*Phaseolus vulgaris* cv.; Arka Komal and Waghya) sown on 31 December 1889 and were supplied with 3 rates of N (0, 25 and 75 kg ha^{-1}). A basal application of half rate of N and full rate of P and K at sowing and a top dressing of a half rate of N after 1 month was applied. Seeds were evaluated for N, P and K contents total dry matter and protein production. The highest P uptake (6.3 kg ha^{-1}) by seeds and straw was recorded in both Waghya and Arka komal. In case of Waghya the highest total dry matter (17.2 q ha^{-1}) was recorded. The highest total P uptake (8.5 kg ha^{-1}) was recorded from the highest N rate (50 kg ha^{-1}). P uptake increased linearly with increase in P rates.

Tewari and Singh (2000) studied from a trial in India to identify the optimum and economical dose of nitrogen (0, 40, 80, 120 or 160 kg ha^{-1}) and phosphorus (0, 20, 40 or 60 kg ha^{-1}) for better growth and yield of French bean. they obtained highest yield of pods per plant, weight of seeds per plant and seed yield with the application of 120 kg N ha^{-1} whereas 160 kg N ha^{-1} significantly reduced seed yield.

Arya *et al.* (1999) performed an experiment to investigate the effect of N, P and K on French bean. They used different doses of NPK combinations. It was concluded that N promoted growth and suggested that 25 kg N ha^{-1}. 75 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} was the best combinations for yield per plant and yield per hectare.

Rana and Singh (1998) seed yield is increased significantly with N rate in French bean. They used 0, 40, 80 and 120 kg N ha^{-1} and 0, 50 or 100kg P_2O_5 ha^{-1}. The mean increase in seed yield with 120 kg N ha^{-1} compared with 0, 40 and 80 kg N ha^{-1} was 66.6, 21.7 and 7.0% respectively.`

Farmer's participatory research conducted in eighty villagers of the North Bank Agroclimatic zone of Assam, India during 1992-95 indicating the possibility of enhancing NPK levels for *P. vulgaris* upto 60-80-40 kg ha^{-1}. Under resources constraint conditions 30-40-20 kg NPK ha^{-1}may be practiced (Baishya and Thakur 1998).

Sushant *et al.* (1998) observed from an experiment in Uttar Pradesh, India to study the effect of irrigation, nitrogen and phosphorus on the seed yield of French bean and reported that application of nitrogen up to 100 kg ha^{-1} up to 60 kg P_2O_5 ha^{-1} significantly increased the yield attributes, yield and water use efficiency.

Gajendra and Singh (1998) performed an experiment at Lalchaoti with moisture regimes and fertility levels in soil on French bean. They stated that 120 kg N + 90 kg P_2O_5 and 45 kg K per ha gave higher fresh pod yield per plant and pod yield per ha and also grain yield in French bean.

Devender *et al.* (1998) carried out an experiment to find out the effect of nitrogen and phosphorus on yield of French bean. Seeds per pod and seed yield were increased significantly up to 15 kg N and 60 kg P_2O_5 ha^{-1}.

Bagal and Jadhav (1995) accomplished an experiment to the study effects of nitrogen *Rhizobium* and nutrient uptake by French bean. Seeds were inoculated with *Rhizobium phaseoli* or not inoculated and the crop was supplied with 0, 12.5, 25 or 37.5 kg N ha^{-1}. Seed yield and total P uptake increased with up to 25 kg N ha^{-1} whereas total N and K uptake increased with up to 37.5 kg N ha^{-1}.

Another field experiment was performed by Khalak and Kumaraswamy (1994) in red loam soil at Bangalore, potatoes cv. Kufri Jyoti to assess the effect on dry mater accumulation and growth attributes of potato as influenced by irrigation and fertilizer (50, 100, or 150 kg ha^{-1} each of N, P_2O_5 and K_2O). They found that leaf area index, leaf area duration, total dry matter accumulation increased with the rate of N + P_2O_5 + K_2O application.

The best yield of *Phaseolus vulgaris* was attained by Thurumalai *et al.* (1993) applying 62.5 kg N + 100kg P_2O_5 + 75 kg K_2O ha^{-1} respectively which only gave an incremental cost: benefit cost (ICBR) of 1:4.12. The most economical treatment used 62.5 kg N + 100kg P_2O_5 + no kg K_2O and produced an ICBR of 1:6.32.

Adetunji (1990) have reported similar findings in beans cultivated with organic manures. Specific leaf weight showed decreasing pattern by increasing the amounts of vermicompost and application of organic mulch. The finding clearly shows that optimum dose of vermicompost and organic mulching play an important role towards partitioning of photo assimilates from vegetative source to reproductive sink (leaf to green pod) which will ultimately lead to development of yield attributes.

Harris (1990) found that earthworm excreta are an excellent soil conditioning material with higher water holding capacity and natural time for releasing nitrogen into the soil. The nutrient level of the vermicompost was about two times greater than natural compost and the use of vermicompost is important for farmers to get better quality crop yields. The fertility efficiency test of vermicompost for tomato, sesame and okra by them also confirmed its positive impact on qualitative and quantitative characteristics of crops.

A field experiment was performed by Shrinivas and Naik (1988) with cv. Arka Komal of French bean to observe the response to nitrogen and phosphorus fertilization. Nitrogen was applied at 0, 40, 80, 120 and 160 kg ha^{-1} and P at 0, 17.5 or 34.9 kg ha^{-1}. Half of the total N and all P plus 33.2 kg ha^{-1}K were applied at sowing and the remaining N was top dressed 25 days later. Pod yields were increased with increasing fertilizer rate from 392 kg ha^{-1}at 0 kg N to 13617 kg ha^{-1} at 160 kg N ha^{-1}.

An experiment was conducted by Sardana and Verma (1987) in New Delhi, India in 1983-84. They stated that the application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in plant height of mungbean.

Bhopal and Singh (1987) accomplished a field experiment in Himachal Pradesh to evaluate the response of French bean to nitrogen and phosphorus fertilization. Nitrogen was applied at 0-80 kg ha^{-1} and P_2O_5 at 2-120 kg ha^{-1}, and a basal dose of K_2O at 50 kg ha^{-1}. The optimum nitrogen phosphorus dose was 67.3: 79.7 kg ha^{-1}; it gave yields over 210 q ha^{-1}.

Panda (1984) observed that though pulses fix atmospheric N still then application of N at the rate of 20 kg ha^{-1} was beneficial. Katock *et al.* (1983) obtained maximum nodule number and nodule weight per plant with 30 kg N ha^{-1} in French bean.

Singh *et al.* (1981) found that seed yields of *Phaseolus vulgaris* were increased significantly with increasing N rates (0-120 kg N ha^{-1}) and with up to 60 kg P_2O_5 ha^{-1}.

2.2 Effect of irrigation frequency:

Tayel and Sabreen (2011) carried out field experiments in clay loam soil during two successive growing seasons to study 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. Faba bean seeds were planted on the 1st week of November and growing season lasted 150 days. Surface drip irrigation method was used. Irrigation water was applied at the rate of 100% of ET_c. 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. They observed that GB Varity, P_1 (20 Kg P_2O_5 $fed.^{-1}$) and irrigation regime IR_1 are recommended under unlimited water resources. Under deficit irrigation in arid and semi-arid regions, using the treatments (GB; P1; IR_2) and (GB; P_1; IR_4) could save 11.4 and 4.7 % of irrigation and in the same time achieve a comparable yield.

Thakur *et al*. (2011) studied that system of rice intensification practices with alternate wet and drying improve rice plants morphology and it benefits physiological processes that results in higher grain yield water productivity.

A field study was carried out during 2003-04, 2004-05 and 2005-06 at Belvatgi in Karnataka, India to study the response of French bean (*Phaseolus vulgaris* L.)

to irrigation schedules, phosphorus levels and phosphorus solubilizer application in Vertisols. Different treatment combinations significantly influenced plant height, branches number, pod length, pod per plant, single pod weight, pod yield per plant and pod yield per ha of French bean during three years and their pooled mean. 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 (Chaudhari, Sahu, Bardhan and Khot 2008).

Ali and Amin (2007) carried out a field experiment in Bangladesh during rabi season to evaluate the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar Shatabdi. Irrigation treatments were given as: no irrigation, control (T0); one irrigation at 21 DAS (T_1); two irrigations at 21 and 45 DAS (T_2); three irrigations at 21, 45 and 60 DAS (T_3); and four irrigation at 21, 45, 60 and 75 DAS (T_4). Significant effects were observed on plant height, number of effective tillers per hill, spike length, number of spikelets per spike, filled grains per spike due to different levels of irrigation. Two irrigations at 21 and 45 DAS significantly increased the growth, yield attributes and yield of wheat over the other treatments. Results also showed that grain yield, straw yield and harvest index were significantly higher at T_2 compared to the other treatments of the study.

Rabbani *et al*. (2004) observed 3 genotypes of soybean under different irrigation frequencies during November 2000 to February 2001 at Mymensingh, Bangladesh. The growth and yield parameters were obtained from 30 to 90 DAS at 15 days intervals. Plant height, leaf area index, crop growth rate, shoot dry weight, number of filled pods plant^{-1}, number of seeds plant^{-1}, seed yield and harvest index were highest with irrigation at 20,40 and 60 DAS. The highest numbers of branches and leaves were evaluated with irrigation at 20, 40, 60 DAS and 20, 40, 60 and 80 DAS. The chlorophyll content increased whereas the number of empty pods decreased with increasing irrigation frequency.

Siowit and Kramer (1997) perceived that the maximum yield reduction in soybean occurred due to moisture stress during bean filling stage. Drastic yield reduction was also observed in mungbean due to water stress (Sadasivam *et al*. 1988, Hamid *et al*. 1990). The yield loss was primarily caused by the reduction of canopy development, inhibition of photosynthetic rate and lower dry matter production

Biswas *et al.* (2001) observed that irrigation frequency exerted a significant effect on yield of Field bean. Application of 3 irrigations increased pod yield about 19% and 13% and seed yield about 53% and 30% over 1 and 2 irrigations respectively. He also reported higher number of flowers per plant, pods per plant, seeds per pod and pod length, pod diameter, pod yield per plant with higher frequency of irrigation and highest with 2 irrigations.

An experiment was conducted in Bangladesh Agricultural Research Institute, Gazipur, to study the effect of irrigation by Rashid (1999), who stated that irrigation was essential for Cabbage and a field capacity below 50% gradually decreased the growth rate. He also added that repeated irrigation was necessary in the dry season for higher yield.

Bhonde *et al*. (1996) perceived that the effect of irrigation frequency and N rate on Onion (*Allium cepa* L.) seed production in Maharashtra using 3 irrigation intervals and 3 rates of N fertilizer. Irrigation at 10 days interval with 80 kg N per hectare in split applications gave the highest yield of good quality seed of onion cv. Agrifound Light Red.

Petersen *et al.* (1989) studied that water stress reduced pods per plant and mean seed weight in *Phaseolus vulgaris*.

Turk *et al.* (1980) performed a field experiment to find out the response of cowpea to intensities of drought at different stages of growth and stated that yields were not decreased by drought imposed during the vegetative stage; substantial yield reduction was obvious while drought occurred during flowering stage. Variation in yields resulted from difference in number of pods/m^2 and small seed size

Dubtez and Mahalle (1969) observed that water stress reduced pod yield of Bush bean by 53%, 71% and 35% when the stress occurred during pre-flowering, flowering and pod formation periods, respectively. Dry weight of pod also increased with increasing water supply efficiency.

Salter and Goode (1997) reported that the amount of yield reduction from water scarcity depends not only on the magnitude of the deficit but also on the stage of growth of Bush bean. Yield and dry matter production were reduced in all growth stages by water deficits. They further studied that when the deficiency of water was decreased the growth rate did not immediately return to normal but required several days to recover.

Kovacs *et al.* (1999) carried out a series of field experiment in Hungary between 1991 and 1994 using 7 irrigation treatments at two fertilizer levels. Irrigations were applied at different growth stages of maize. They determined the relationship between relative yield and relative evapotranspiration as well as those between the crop yield and water use.

CHAPTER III

MATERIALS AND METHODS

The materials and methods used in execution of the experiment have been presented in this chapter. It deals with a short description of location of the experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis.

3.1 Location of the experimental plot

The research work was carried out at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of fertilizer management and irrigation schedule on growth and yield of French bean during the period from November 2016 to March 2017.The Experimental site was located at 90°22′ E longitude and 23°41′ N latitude and altitude of 8.2 m above the sea level.

3.2 Climatic condition

The experimental site is located in subtropical region where climate is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low temperature and short day period during "Rabi" season (October-March). During the month of October, November, December and January, there was no rainfall. During the period of experiment, the average maximum temperature was 25.8˚C and the average minimum temperature was 16.0˚C. The meteorological data in respect of temperature, rainfall and relative humidity during the period of the research work were collected from Weather Station of Agargaon, Dhaka.

3.3 Characteristics of soil

The soil of the research area was under the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was Non- calcareous, dark gray and medium high. The texture of soil is sandy loam and pH of soil is 5.5. The soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka.

3.4 Planting materials:

The French bean cultivar i.e. BARI Jhar Sheem 1 was used in this experiment. The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatments of the experiment:

The experiment consists of two factors as follows:

Factor A: Nutrient management

i. F_1: 0 (Control)
ii. F_2: $N_{60}+P_{20}+K_{30}$
iii. F_3: Vermicompost (10 t ha^{-1})
iv. F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Factor B: Irrigation frequency

i. I_1: 3 days interval
ii. I_2: 6 days interval
iii. I_3: 9 days interval

The treatment combinations were:

F_1I_1, F_1I_2, F_1I_3, F_2I_1, F_2I_2, F_2I_3, F_3I_1, F_3I_2, F_3I_3, F_4I_1, F_4I_2, F_4I_3

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 95.76 m^2 with length 16.8 m and width 5.7 m. The total area was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were allotted at random. There were 36 unit plots altogether in the experiment. The size of the each plot was 0.9 m $\times$ 0.9 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment field is presented in Fig. 1.

3.7 Land preparation

The experimental land was first ploughed with the help of a power tiller and the soil was exposed to sun for 5 days. Then the land was well prepared by ploughing and cross ploughing. The weeds and stubbles were removed from the field. Then the land was divided into 36 unit plots keeping plot and block to block spacing. For controlling soil borne insects, carbofuran @ 16 kg ha^{-1} was mixed with the soil uniformly during land preparation.

3.8 Application of manures and fertilizers

Manures and fertilizers were applied according to treatment. The entire amount of vermicompost, triple super phosphate (TSP) and muriate of potash (MP) were applied and mixed with the soil during final land preparation. Nitrogen was applied as per treatment in the form of urea. The 1/3 amount of urea was applied during final land preparation and rests amount of urea in two installments at 15 and 30 days after sowing the seeds. The applied fertilizers were mixed properly with the soil of the plot.

3.9 Sowing of seeds

Two seeds were sown per hill at a depth of 3.0 cm on 17th November, 2016 in row. During sowing seeds, plant to plant distance was maintained 15 cm and row to row distance was maintained 30 cm. Just after sowing, the seeds were covered with pulverized soil and gently pressed with hands. Surrounding of the experimental plots, French been seeds were also sown as border crop to reduce border effects.

3.10 Application of irrigation as treatment

In some plots irrigation is applied at 3 days interval. Irrigation is given at 6 days interval in some plots and at 9 days interval in other plots.

3.11 Intercultural Operations

3.11.1 Gap filling

Few seeds were sown in the border of the plots during seed sowing. Seedlings were transferred to fill up the gap where seeds failed to germinate. Seedlings of about 15 cm in height were transplanted from border rows with roots plunged 5 cm below the soil in hills in the evening. Then watering was done to protect the seedlings from wilting. Within two weeks after germination of seeds, all gaps were filled up.

3.11.2 Thinning

One healthy plant per hill was kept when the plants were established and remaining one was plucked.

3.11.3 Weeding

To keep the crop free from weeds, weeding was done whenever necessary. The experimental plots were kept weed free by hand weeding.

3.11.4 Staking

When the seedlings were established, staking was given to each plant. Bamboo stick was given to support the growing twig.

3.11.5 Stem management

The stems were managed upward with the help of bamboo and plastic rope for proper growth and development of the plants. So, the rainy and stormy weather could not injure the growing vines and fruits of the plants.

3.12 Plant protection

3.12.1 Insect pests

Some plants were invaded by insect pests (mainly aphids) at the early stage of growth and Malathion 57 EC was applied at the rate of 2 ml/liter at an interval of 15 days to control the insects

.3.12.2 Diseases

Some plants were affected by Bean common mosaic virus (BCMV) which was an important disease of French bean. These plants were removed from the plots and destroyed immediately.

3.12.3 Harvesting

When the green pods were in marketable condition, they were harvested through hand picking and weighed to calculate the yield of fresh pod. At harvest, pods were nearly full size, with the seeds still small (about one quarter developed) with firm flesh (Swiader *et al*., 1992) and the pods were soft and smooth.

3.13 Data collection

Five plants were chosen randomly from each plot to avoid border effect and tagged in the field. Data were collected in respect of the following parameters to measure plant growth, yield attributes and yields as influenced by different treatments of the experiment. Data on plant height, number of branches, number of leaves, leaf size and number of flowers were recorder at 15, 30 and 45 days after sowing (DAS). All other yield contributing parameters were recorded during harvest and after harvest.

3.13.1 Plant height

Plant height was measured in centimeter from ground level to tip of the largest leaf from sample plants of each treatment and mean value was calculated.

3.13.2 Number of branches per plant

The number of branches of five randomly selected plants from each plot was collected and mean value was calculated.

3.13.3 Number of leaves per plant

The number compound leaves of five randomly selected plants from each plot was counted and mean were calculated.

3.13.3 Leaf length

Leaf length (cm) of five randomly selected plants from each plot was measured by using measuring scale and mean was recorded.

3.13.4 Leaf breadth

Leaf breadth (cm) of 5 randomly selected plants from each plot was measured by using measuring scale and mean was recorded.

3.13.5 Number of flowers per plant

From five randomly selected plants from each plot, the number of flowers were counted and their mean values were calculated.

3.13.6 Number of pods per plant

Number of pods from five randomly selected plants were measured and their mean values were calculated.

3.13.7 Length of green pod

Five pods from each randomly selected plant were measured with the help of centimeter scale and the mean value was calculated and was expressed in centimeter.

3.13.8 Diameter of green pod

Diameters of green pod of five randomly selected plants from each plot were measured in cm by using slide calipers and their average was taken and was expressed in centimeter.

3.13.9 Individual pod weight

Pods of each selected plants were weighed and their average was measured in gram (g).

3.13.10 Pod yield per plant

Green pods from each unit plot were weighted and their mean was recorded in gram (g).

3.13.11 Pod yield per plot

Green pods were harvested at regular interval from each unit plot and their weight was recorded. As harvesting was done at different and the total pod weights were recorded in each unit plot and expressed in gram (g).

3.13.12 Pod yield per hectare

The green pod yield per plot was finally converted to yield per hectare and expressed in ton (t).

3.13.13 Dry matter content of pods

100 g pods from each plot were taken, cut into some small pieces and was dried under direct sunshine for 3 days and then was dried in an oven at 70^0 for 72 hours before taking the dry weight till it was constant. The dry weight was recorded in gram (g) by using a beam balance.

3.14 Statistical analysis

The data obtained for different characters were statistically analyzed by using SPSS computer package program to find out the effect of fertilizers and irrigation schedule on yield and yield contributing characters of French bean. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the “F” (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan‟s Multiple Range Test (DMRT) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the response of growth and yield of French bean (*Phaseolus vulgaris* L.) under different fertilizer management and irrigation schedule. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The results have been presented and discussed with the help of tables and graphs and possible interpretation has been given under the following headings.

4.1 Crop growth characters

4.1.1 Plant height

There was a great variation on plant height of French bean influenced by different nutrient sources at different growth stages (Fig. 2). It was noted that the highest plant height (27.43, 37.80 and 46.37 cm at 15, 30 and 45 DAS, respectively) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) which was statistically identical with F_3 (Vermicompost @ 10 t ha^{-1}) treatment at all growth stages. At 15 and 30 DAS, the treatment F_2 (N_{60}+P_{20}+K_{30}) was also statistically identical with F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}). Similarly, the lowest plant height (24.81, 31.81 and 38.16 cm at 15, 30 and 45 DAS, respectively) was achieved from control treatment (F_1) which was significantly different from other treatments. The result on plant height obtained was similar with findings of Islam *et al*. (2016), Sarma *et al*. (2014) and Singh *et al*. (2009).

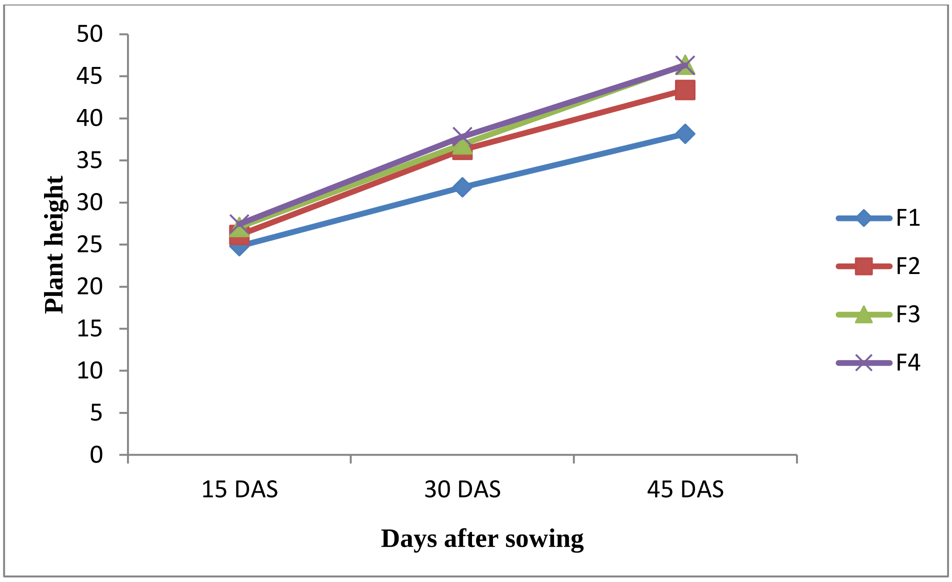

Fig. 2. Effect of nutrient sources on plant height of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Plant height was significantly influenced by different irrigation levels at different growth stages (Fig. 3). Results revealed that the highest plant height (28.20, 38.61 and 44.78 cm at 15, 30 and 45 DAS, respectively) was recorded from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) at all growth stages. The lowest plant height (23.71, 31.25 and 40.93 cm at 15, 30 and 45 DAS, respectively) was found from the irrigation treatment of I_3 (9 days interval irrigation). Similar result on plant height affected by different irrigation schedule was also observed by Rabbani *et al*. (2004) and (Chaudhari, Sahu, Bardhan and Khot, 2008).

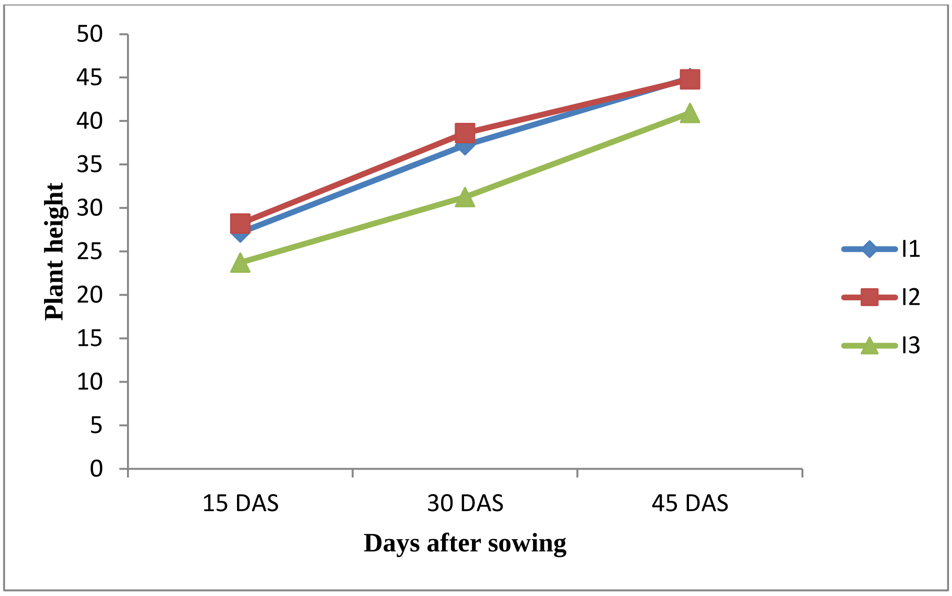

Fig. 3. Effect of irrigation frequency on plant height of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Significant variation was observed on plant height of French bean at different growth stages influenced by combined effect of nutrient sources and irrigation frequency (Table 1). The highest plant height (30.33, 41.83 and 51.43 cm at 15, 30 and 45 DAS, respectively) was achieved from the treatment combination of F_4I_2 which was significantly different from all other treatment combinations followed by the treatment combinations of F_3I_1. The lowest plant height (21.53, 28.60 and 36.65 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 which was also significantly different from others. The treatment combination of F_1I_1 and F_1I_2 also showed lower plant height compared to other treatment combinations but significantly different.

Table1. Combined effect of nutrient sources and irrigation frequency on plant height of French bean

Treatments	Plant height (cm) at		
	15 DAS	30 DAS	45 DAS
F_1I_1	26.28 g	32.33 e	38.53 k
F_1I_2	26.60 f	34.50 d	39.28 j
F_1I_3	21.53 k	28.60 g	36.65 l
F_2I_1	27.20 e	38.49 c	46.00 c
F_2I_2	27.60 cd	38.84 bc	42.77 g
F_2I_3	23.60 j	31.47 f	41.33 i
F_3I_1	27.47 d	38.83bc	50.00 b
F_3I_2	28.27 b	39.28 b	45.62 d
F_3I_3	25.53 h	32.63 e	43.50 f
F_4I_1	27.80 c	39.27 b	45.27 e
F_4I_2	30.33 a	41.83 a	51.43 a
F_4I_3	24.17 i	32.30 e	42.23 h
SE (±)	0.38	0.68	0.72
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.1.2 Number of branches plant^{-1}

Number of branches plant^{-1} at different growth stages was significantly varied due to different nutrient sources (Fig. 4). It was found that the highest number of branches plant^{-1} (1.81, 5.48 and 9.23 at 15, 30 and 45 DAS, respectively) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}). At 45 DAS, it was significantly different from other treatments but at 15 and 30 DAS it was statistically similar with F_2 (N_{60}+P_{20}+K_{30}) treatment. The lowest number of branches plant^{-1} (1.13, 4.33 and 7.29 at 15, 30 and 45 DAS, respectively) was found from control treatment (F_1). Similar result was also observed by Singh *et al*. (2011) and Dhanjal *et al*. (2001).

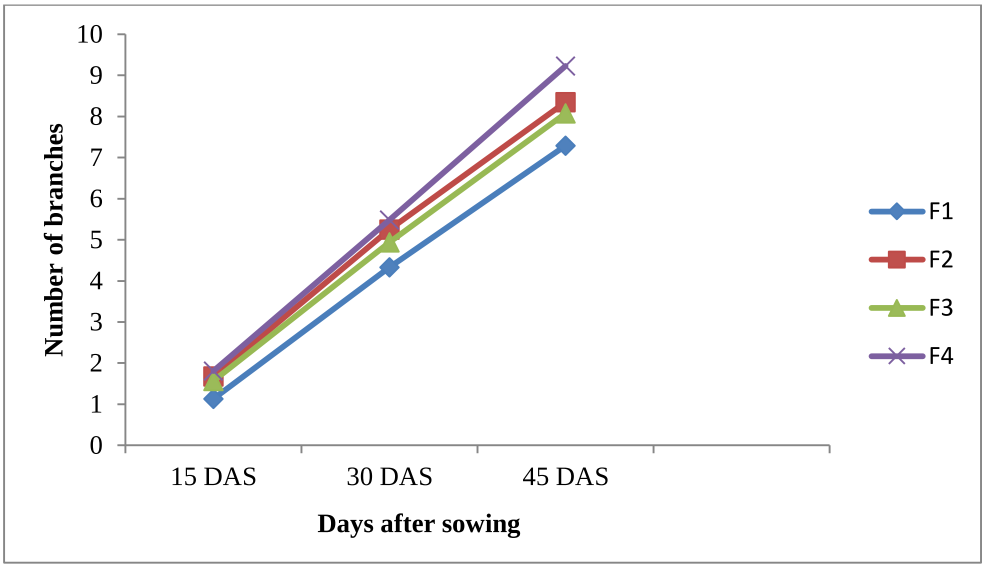

Fig. 4. Effect of nutrient sources on number of branches per plant of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Remarkable variation was observed on number of branches plant^{-1} at different growth stages influenced by different irrigation levels (Fig. 5). It was evident that the highest number of branches plant^{-1} (1.81, 5.65 and 8.97 at 15, 30 and 45 DAS, respectively) was achieved from the irrigation level of I_2 (6 days interval irrigation) and at 45 DAS it was statistically identical with the treatment I_1 (3 days interval irrigation). The lowest number of branches plant^{-1} (1.28, 4.28 and 7.46 at 15, 30 and 45 DAS, respectively) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). Water stress significantly reduced number of branches plant^{-1} observed by Rabbani *et al*. (2004) and Khot *et al*. (2008).

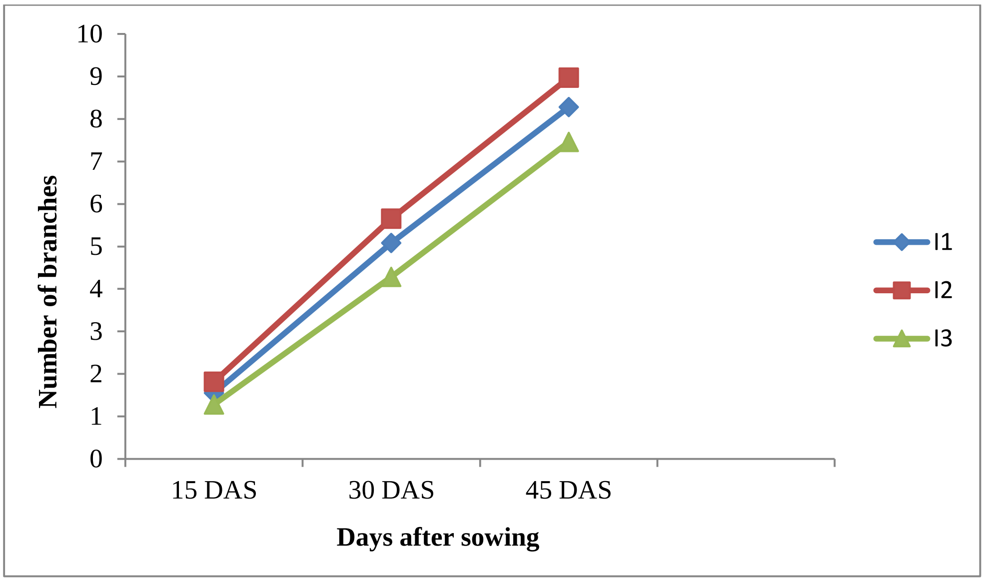

Fig. 5. Effect of irrigation frequency on number of branches per plant of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Significant influence was noted on number of branches plant^{-1} affected by combined effect of nutrient sources and irrigation frequency at different growth stages (Table 2). It was observed that the highest number of branches plant^{-1} (2.10, 6.25 and 10.22 at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_4I_1 and F_2I_2. The lowest number of branches plant^{-1} (0.98, 3.91 and 6.77 at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 which was significantly different from other treatment combinations but the treatment combinations of F_1I_1 and F_1I_2 also showed lower number of branches plant^{-1} compared to others.

Table 2. Combined effect of nutrient sources and irrigation frequency on number of branches per plant of French bean

Treatments	Number of branches plant^{-1} at		
	15 DAS	30 DAS	45 DAS
F_1I_1	1.10 g	4.46 g	7.45 k
F_1I_2	1.30 f	4.62 e	7.65 j
F_1I_3	0.98 h	3.91 i	6.77 l
F_2I_1	1.70 c	5.51 d	7.92 e
F_2I_2	1.97 b	5.92 b	9.34 c
F_2I_3	1.37ef	4.32 h	7.78 g
F_3I_1	1.50 d	4.55 f	7.88 f
F_3I_2	1.87 b	5.82 c	8.67 d
F_3I_3	1.35 ef	4.45 g	7.68 h
F_4I_1	1.91 b	5.78 c	9.88 b
F_4I_2	2.10 a	6.25 a	10.22 a
F_4I_3	1.42 de	4.42 g	7.60 i
SE (±)	0.06	0.13	0.17
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton/ha) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.1.3 Number of compound leaves plant^{-1}

Number of compound leaves plant^{-1} varied significantly due to different nutrient sources at different growth stages (Fig. 6). Results showed that the highest number of compound leaves plant^{-1} (3.90, 10.21 and 17.21 at 15, 30 and 45 DAS, respectively) was achieved from the treatment F_4 ($N_{30}+P_{10}+K_{15}$ + Vermicompost @ 5 t ha^{-1}) which was closely followed by F_2 ($N_{60}+P_{20}+K_{30}$) treatment at 45 DAS but it was statistically identically at 15 and 30 DAS. Again, the lowest number of compound leaves plant^{-1} (3.28, 9.27 and 15.03 at 15, 30 and 45 DAS, respectively) was found from control treatment (F_1). The result observed from the present study was similar with the findings of Saxena *et al*. (2003).

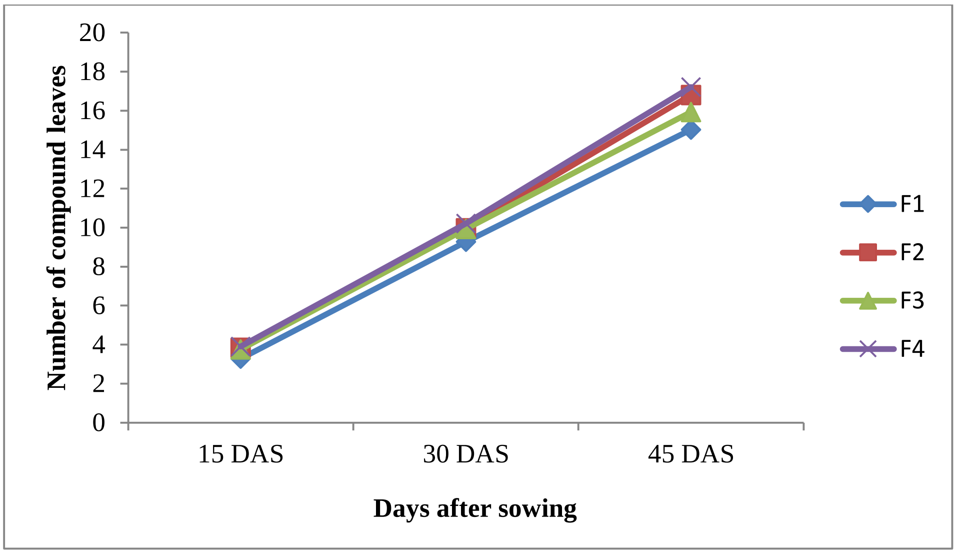

Fig 6. Effect of nutrient sources on number of compound leaves per plant of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Significant variation was remarked as influenced by different irrigation levels at different growth stages (Fig. 7). Results signified that the highest number of compound leaves plant^{-1} (3.85, 10.38 and 17.46 at 15, 30 and 45 DAS, respectively) was recorded from the irrigation level of I_2 (6 days interval irrigation) followed by I_1 (3 days interval irrigation) whereas the lowest number of compound leaves plant^{-1} (3.55, 9.43 and 15.12 at 15, 30 and 45 DAS, respectively) was obtained from the irrigation treatment of I_3 (9 days interval irrigation). Rabbani *et al.* (2004) also found similar result.

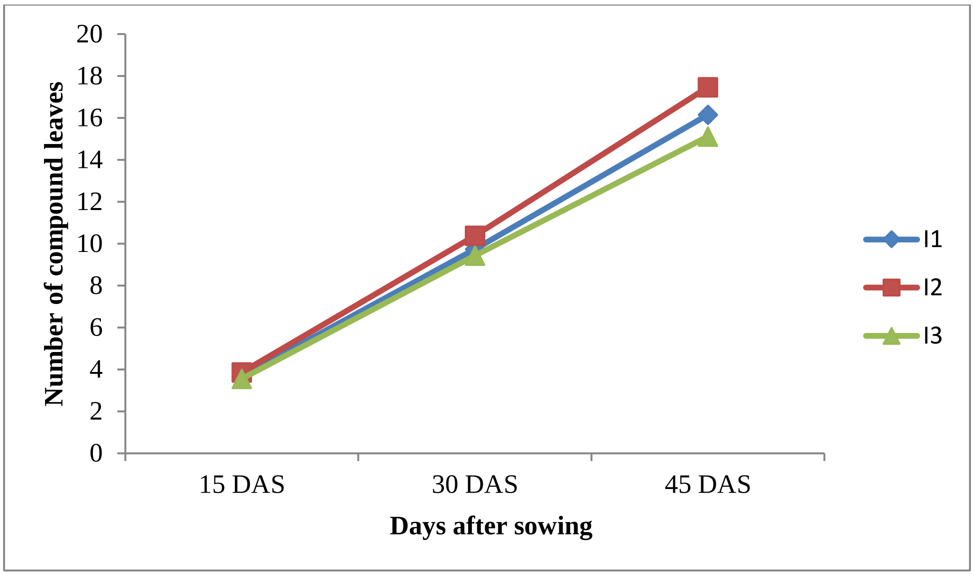

Fig. 7. Effect of irrigation frequency on number of compound leaves of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Number of compound leaves plant^{-1} was found significant with combined effect of nutrient sources and irrigation frequency at different growth stages (Table 3). The highest number of compound leaves plant^{-1} (4.10, 11.16 and 19.48 cm at 15, 30 and 45 DAS, respectively) was achieved from the treatment combination of F_4I_2 followed by the treatment combination of F_2I_2. The lowest number of compound leaves plant^{-1} (3.03, 8.92 and 14.21 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 followed by the treatment combination of F_1I_1 and F_3I_3.

Table 3. Combined effect of nutrient sources and irrigation frequency on number of compound leaves per plant of French bean

Treatments	Number of compound leaves plant^{-1} at		
	15 DAS	30 DAS	45 DAS
F_1I_1	3.25 g	9.38 j	15.25 j
F_1I_2	3.55 f	9.52 i	15.62 h
F_1I_3	3.03 h	8.92 j	14.21 l
F_2I_1	3.88 b	9.78 f	16.85 c
F_2I_2	3.92 b	10.56 b	17.92 b
F_2I_3	3.73 de	9.57 h	15.64 g
F_3I_1	3.75 d	9.88 e	15.78 f
F_3I_2	3.81 c	10.28 c	16.82 d
F_3I_3	3.68 e	9.66 g	15.21 k
F_4I_1	3.81 c	9.92 d	16.73 e
F_4I_2	4.10 a	11.16 a	19.48 a
F_4I_3	3.77 cd	9.56 h	15.43 i
SE (±)	0.05	0.10	0.23
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton/ha) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.1.4 Leaf length

Variation on leaf length was noted significant at different growth stages influenced by different nutrient sources (Fig. 8). Results signified that the highest leaf length (9.17, 10.01 and 10.78 cm at 15, 30 and 45 DAS, respectively) was achieved from the treatment F_4 ($N_{30}+P_{10}+K_{15}$ + Vermicompost @ 5 t ha^{-1}) and at all growth stages it was statistically identical with F_2 ($N_{60}+P_{20}+K_{30}$) and F_3 (Vermicompost @ 10 t ha^{-1}) treatments. The lowest leaf length (8.35, 8.76 and 9.42 cm at 15, 30 and 45 DAS, respectively) was achieved from the treatment F_1 (Control). Yourtchi *et al*. (2013), Saxena *et al*. (2003) and Khalak and Kumaraswamy (1994) also found similar results.

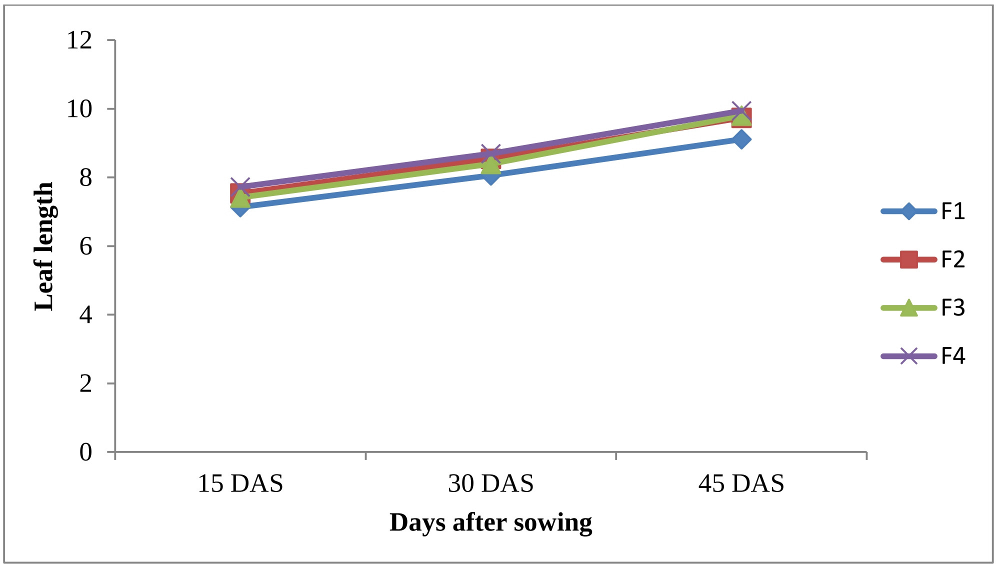

Fig. 8. Effect of nutrient sources on leaf length of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Leaf length of French bean at different growth stages affect by different irrigation frequency was significant (Fig. 9). Results revealed that the highest leaf length (9.20, 9.96 and 10.81 cm at 15, 30 and 45 DAS, respectively) was found from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) at all growth stages but the lowest leaf length (8.55, 9.11 and 9.97 cm at 15, 30 and 45 DAS, respectively) was found from the irrigation treatment of I_3 (9 days interval irrigation). Similar finding on was also achieved by Rabbani *et al*. (2004).

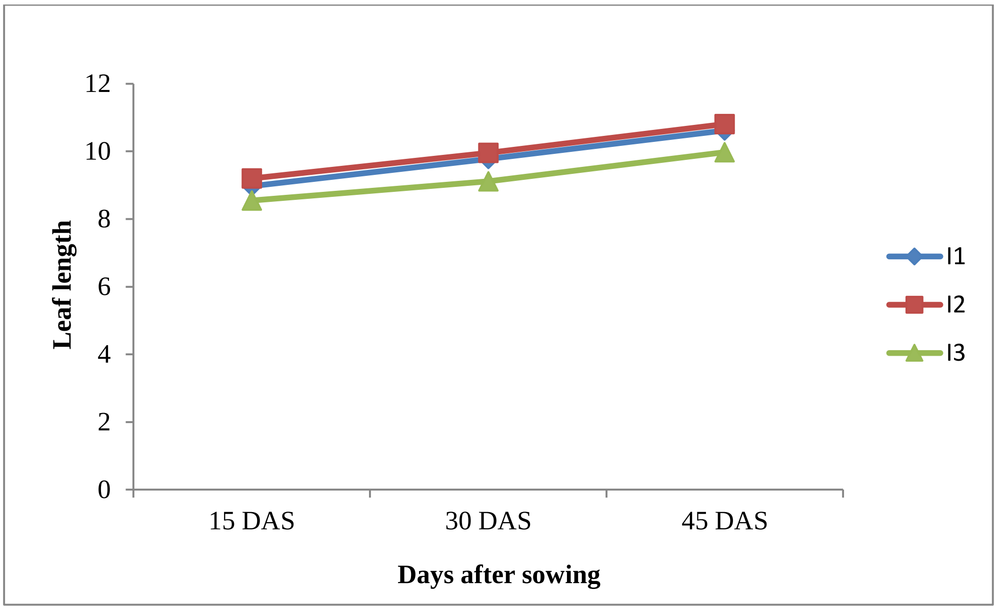

Fig. 9. Effect of irrigation frequency on leaf length of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

The recorded data on leaf length at different growth stages was significant with the combined effect of nutrient sources and irrigation frequency (Table 4). The highest leaf length (9.51, 10.61 and 11.45 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_3I_2. The lowest leaf length (7.63, 7.83 and 8.83 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 followed by the treatment combination of F_1I_1.

Table 4. Combined effect of nutrient sources and irrigation frequency on leaf length of French bean

Treatments	Leaf length (cm) at		
	15 DAS	**30 DAS**	**45 DAS**
F_1I_1	8.61 i	9.18 j	9.61 j
F_1I_2	8.81 h	9.26 i	9.81 i
F_1I_3	7.63 j	7.83 k	8.83 k
F_2I_1	8.92 f	9.76 f	10.68 f
F_2I_2	9.24 b	9.82 d	10.77 e
F_2I_3	8.84 g	9.54 g	10.58 h
F_3I_1	9.16 e	10.08 c	11.12 c
F_3I_2	9.22 c	10.16 b	11.22 b
F_3I_3	8.93 f	9.78 e	10.66 g
F_4I_1	9.19 d	10.09 c	11.07 d
F_4I_2	9.51 a	10.61 a	11.45 a
F_4I_3	8.82 h	9.28 h	9.82 i
SE (±)	0.08	0.11	0.13
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.1.5 Leaf breadth

Considerable influence was observed on leaf breadth at different growth stages persuaded by different nutrient sources (Fig. 10). It was observed that the highest leaf breadth (7.72, 8.69 and 9.94 cm at 15, 30 and 45 DAS, respectively) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) and this treatment was was statistically identical with F_2 (N_{60}+P_{20}+K_{30}) at 30 and 45 DAS. The lowest leaf breadth (7.14, 8.06 and 9.11 cm at 15, 30 and 45 DAS, respectively) was found from the treatment F_1 (Control). Similar findings were also observed by Yourtchi *et al*. (2013) and Saxena *et al*. (2003).

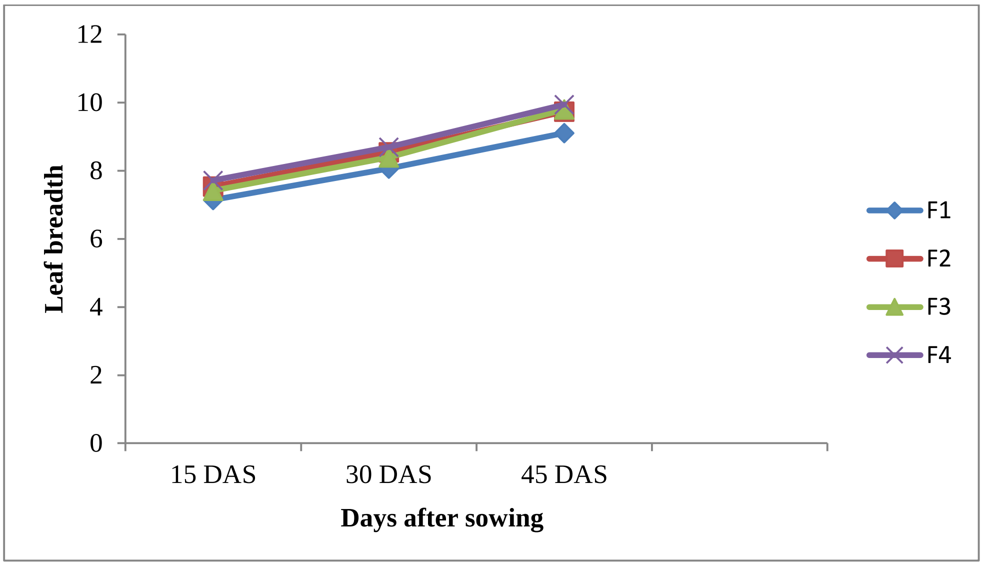

Fig. 10. Effect of nutrient sources on leaf breadth of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Remarkable variation was identified on leaf breadth of French bean due to the effect of different irrigation levels (Figure11). Results showed that the highest leaf breadth (7.72, 8.71 and 9.94 cm at 15, 30 and 45 DAS, respectively) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) at 45 DAS whereas the lowest leaf breadth (7.19, 8.12 and 9.27 cm at 15, 30 and 45 DAS, respectively) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). Rabbani *et al*. (2004) also observed similar result.

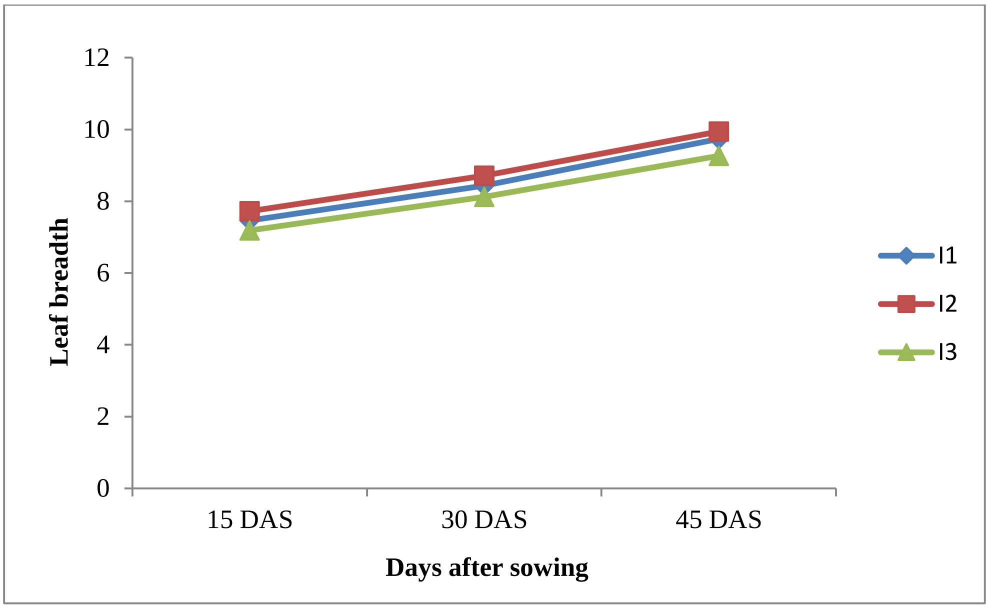

Fig. 11. Effect of irrigation frequency on leaf breadth of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Significant influence was noted on leaf breadth at different growth stages affected by combined effect of nutrient sources and irrigation frequency (Table 5). The highest leaf breadth (8.17, 9.06 and 10.32 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_2I_2 and F_4I_1. The lowest leaf breadth (6.66, 7.48 and 8.68 cm at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 followed by F_1I_1, F_1I_2 and F_2I_3.

Table 5. Combined effect of nutrient sources and irrigation frequency on leaf breadth of French bean

Treatments	Leaf breadth (cm) at		
	15 DAS	30 DAS	45 DAS
F_1I_1	7.35 i	8.32 i	9.30 g
F_1I_2	7.42 g	8.38 g	9.34 g
F_1I_3	6.66 k	7.48 l	8.68 h
F_2I_1	7.58 d	8.56 e	9.78 d
F_2I_2	7.68 b	8.71 b	10.12 b
F_2I_3	7.37 h	8.36 h	9.32 g
F_3I_1	7.37 h	8.30 j	9.76 d
F_3I_2	7.60 c	8.68 c	9.98 c
F_3I_3	7.28 j	8.20 k	9.67 e
F_4I_1	7.56 e	8.58 d	10.10 b
F_4I_2	8.17 a	9.06 a	10.32 a
F_4I_3	7.44 f	8.42 f	9.41 f
SE (±)	0.06	0.06	0.075
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.2 Yield contributing characters

4.2.1 Number of flowers plant^{-1}

Remarkable variation was observed on number of flowers plant^{-1} at different growth stages of French bean influenced by different nutrient sources (Fig. 12). It was noted that the highest number of flowers plant^{-1} (6.76, 12.17 and 18.87 at 15, 30 and 45 DAS, respectively) was found from the treatment F_4 ($N_{30}+P_{10}+K_{15}$ + Vermicompost @ 5 t ha^{-1}) which was statistically identical with F_3 (Vermicompost @ 10 t ha^{-1}) at all growth stages. The treatment F_2 ($N_{60}+P_{20}+K_{30}$) was also statistically identical with F_4 ($N_{30}+P_{10}+K_{15}$ + Vermicompost @ 5 t ha^{-1}) at 15 30 DAS. The lowest number of flowers plant^{-1} (4.32, 8.41 and 13.27 at 15, 30 and 45 DAS, respectively) was found from the treatment F_1 (Control). Similar result was also observed by Singh *et al*. (2009).

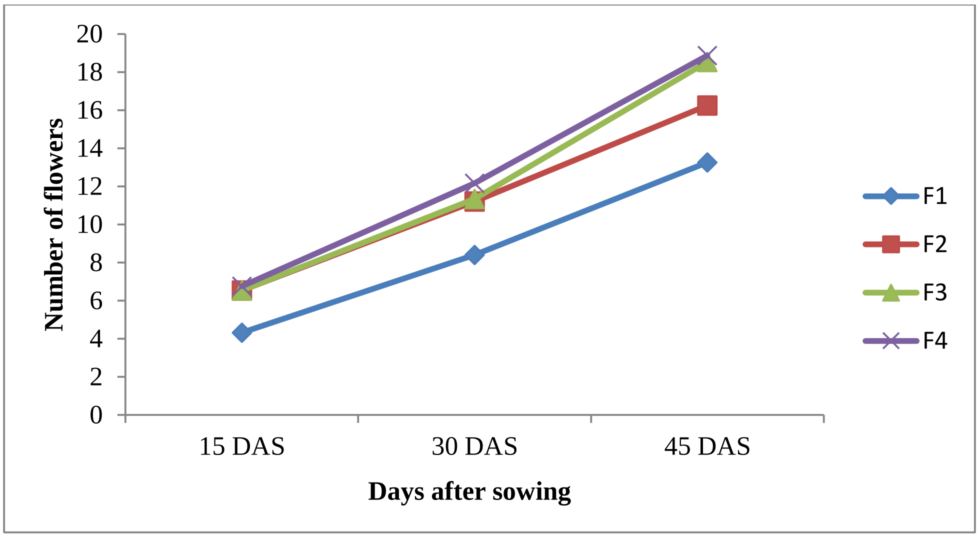

Fig. 12. Effect of nutrient sources on number of flowers per plant of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Significant influence was noted on number of flowers plant^{-1} at different days after sowing affected by different irrigation frequency (Fig. 13). The highest number of flowers plant^{-1} (6.78, 12.34 and 18.57 at 15, 30 and 45 DAS, respectively) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically similar with I_1 (3 days interval irrigation) at 45 DAS where the lowest number of flowers plant^{-1} (5.10, 9.58 and 14.81 at 15, 30 and 45 DAS, respectively) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). Biswas (2001) and Dubtez and Mahalle (1969) also found similar results.

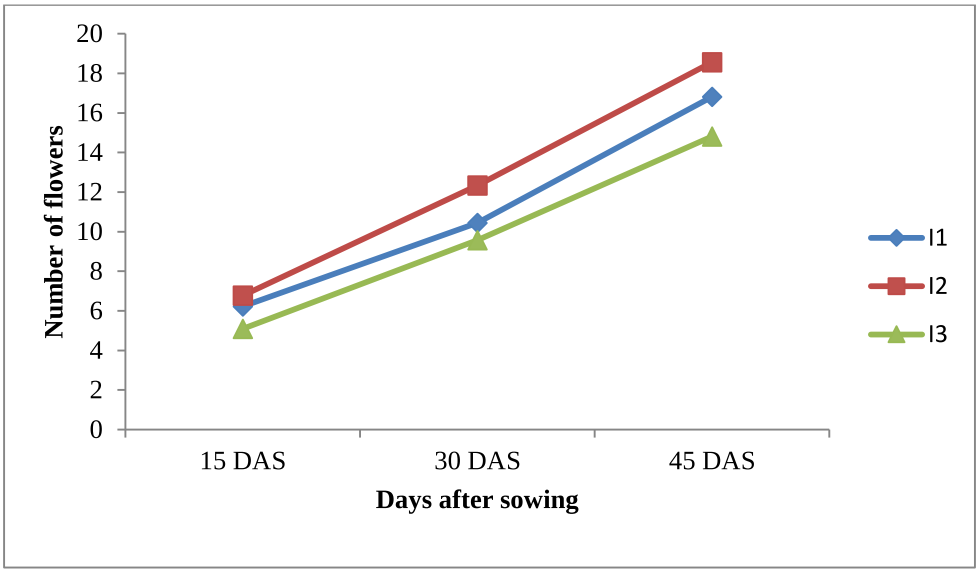

Fig. 13. Effect of irrigation frequency on number of flowers per plant of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Variation on number of flowers plant^{-1} was noted as significant at different days after sowing influenced by combined effect of nutrient sources and irrigation frequency (Table 6). The highest number of flowers plant^{-1} (7.81, 14.61 and 21.84 at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_4I_2. The treatment combination of F_3I_2, F_4I_1 and F_3I_1 also showed comparatively higher number of flowers plant^{-1} but significantly different from others. The lowest number of flowers plant^{-1} (4.03, 8.20 and 12.82 at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3 followed by the treatment combination of F_1I_1.

Table 6. Combined effect of nutrient sources and irrigation frequency on number of flowers per plant of French bean

Treatments	Number of flowers plant^{-1} at		
	15 DAS	**30 DAS**	**45 DAS**
F_1I_1	4.30 k	8.41 j	13.34 k
F_1I_2	4.62 j	8.61 i	13.65 j
F_1I_3	4.03 l	8.20 l	12.82 l
F_2I_1	6.88 e	10.82 f	15.88 g
F_2I_2	7.14 c	12.91 c	18.25 e
F_2I_3	5.60 g	9.94 h	14.62 i
F_3I_1	6.81 f	10.88 e	18.95 d
F_3I_2	7.55 b	13.24 b	20.51 b
F_3I_3	5.25 i	9.93 h	16.16 f
F_4I_1	6.92 d	11.64 d	19.12 c
F_4I_2	7.81 a	14.61 a	21.84 a
F_4I_3	5.54 h	10.25 g	15.64 h
SE (±)	0.21	0.33	0.48
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.2.2 Number of pods plant^{-1}

Considerable influence was observed on number of pods plant^{-1} persuaded by different nutrient sources (Fig. 14). It was recorded that the highest number of pods plant^{-1} (23.54) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) followed by F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}). The lowest number of pods plant^{-1} (19.77) was found from the treatment F_1 (Control). The finding on number of pods plant^{-1} obtained from the present study was similar with the findings of Singh *et al.* (2011), Singh *et al.* (2009) and Kumar *et al.* (2004).

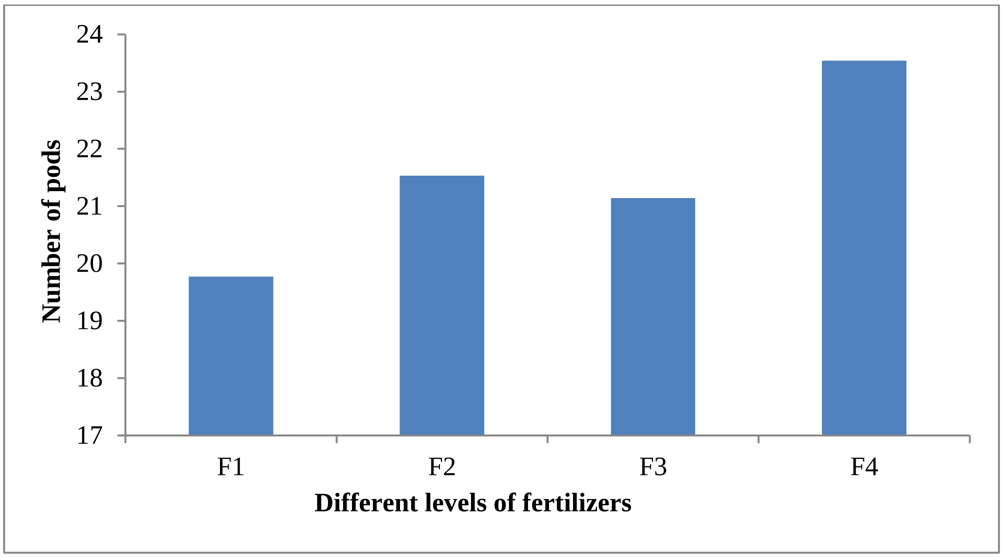

Fig. 14. Effect of nutrient sources on number of pods of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Remarkable variation was identified on number of pods plant^{-1} of French bean due to the effect of different irrigation levels (Fig.15). The highest number of pods plant^{-1} (22.75) was achieved from the irrigation level of I_2 (6 days interval irrigation) where the lowest number of pods plant^{-1} (20.52) was achieved from the irrigation treatment of I_3 (9 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) treatment. Water stress significantly reduced number of pods plant^{-1} achieved by Rabbani *et al.* (2004), Khot *et al.* (2008) and Biswas (2001).

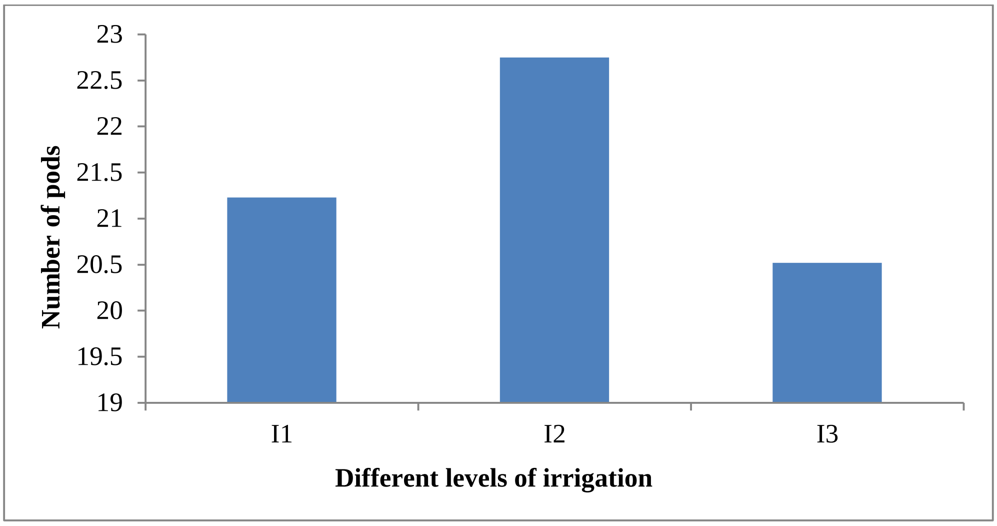

Fig.15. Effect of irrigation frequency on number of pods of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Significant influence was noted on number of pods plant^{-1} affected by combined effect of nutrient sources and irrigation frequency (Table 7). The highest number of pods plant^{-1} (24.81) was recorded from the treatment combination of F_4I_2. The treatment combination of F_4I_1 and F_2I_2 also showed comparatively higher number of pods plant^{-1} but significantly different from others. The lowest number of pods plant^{-1} (18.96) was recorded from the treatment combination of F_1I_3 followed by the treatment combination of F_1I_1 and F_2I_3.

4.2.3 Pod length

Significant influence was found on pod length affected by different nutrient sources (Fig. 16). Results indicated that the highest pod length (11.96 cm) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) which was statistically identical with F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}) where the lowest pod length (10.28 cm) was found from the treatment F_1 (Control). Singh *et al*. (2011) and Singh *et al*. (2009) also found similar results.

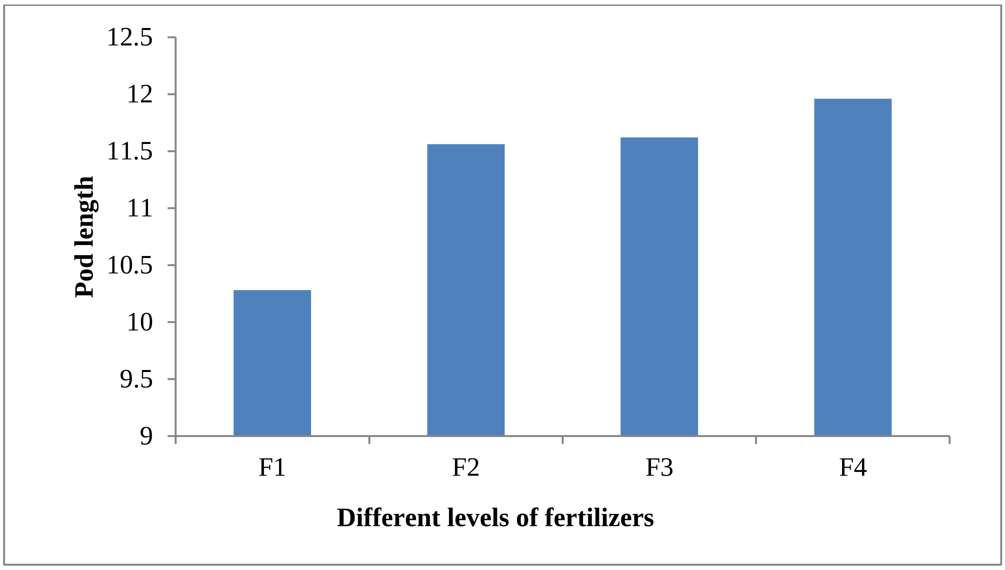

Fig. 16. Effect of nutrient sources on pod length of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Considerable influence was observed on pod length influenced by different irrigation levels (Fig. 17). It was found that the highest pod length (12.08 cm) was achieved from the irrigation level of I_2 (6 days interval irrigation) where the lowest pod length (10.76 cm) was achieved from the irrigation treatment of I_3 (9 days interval irrigation) which was statistically same with I_1 (3 days interval irrigation) treatment. Khot *et al*. (2008) and Biswas (2001) also found similar results.

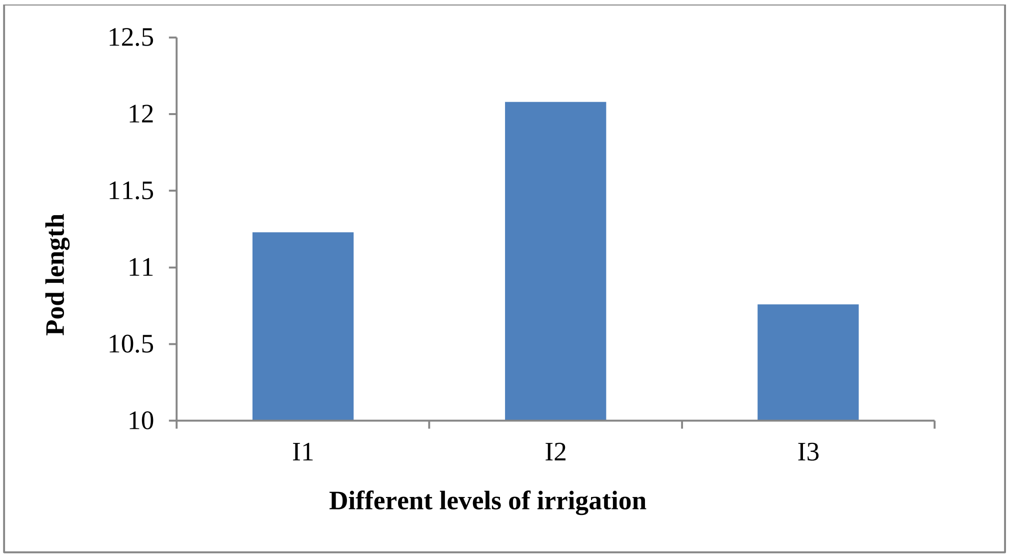

Fig. 17. Effect of irrigation frequency on pod length of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Notable variation was identified on pod length of French bean due to the combined effect of nutrient sources and irrigation frequency (Table 7). Results revealed that the highest pod length (13.22 cm) was recorded from the treatment combination of F_4I_2 which was significantly different from all other treatment combinations. But the treatment combination of F_3I_2, F_2I_2 and F_4I_1 also showed comparatively higher pod length. The lowest pod length (9.86 cm) was recorded from the treatment combination of F_1I_3 which was also significantly different from other treatment combinations. The treatment combination of F_1I_1, F_1I_2 and F_4I_3 also showed lower pod length.

4.2.4 Pod diameter

Considerable influence was observed on pod diameter affected by different nutrient doses (Fig. 18). The highest pod diameter (1.03 cm) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) which was statistically identical with F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}) where the lowest pod diameter (0.91 cm) was found from the treatment F_1

(Control). Similar results on pod diameter were also achieved by Singh *et al*. (2011) and Kumar *et al*. (2004).

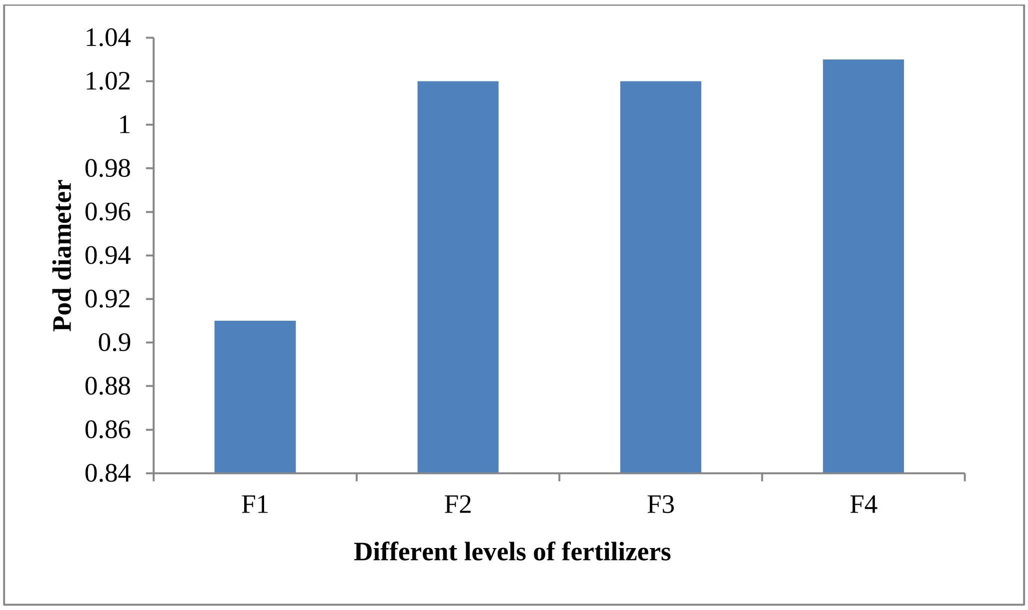

Fig. 18. Effect of nutrient sources on pod diameter of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Remarkable variation was identified on pod diameter due to the effect of different irrigation levels (Fig. 19). The highest pod diameter (1.03 cm) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) where the lowest pod diameter (0.96 cm) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). Biswas (2001) also found similar result on pod diameter that supported the present finding.

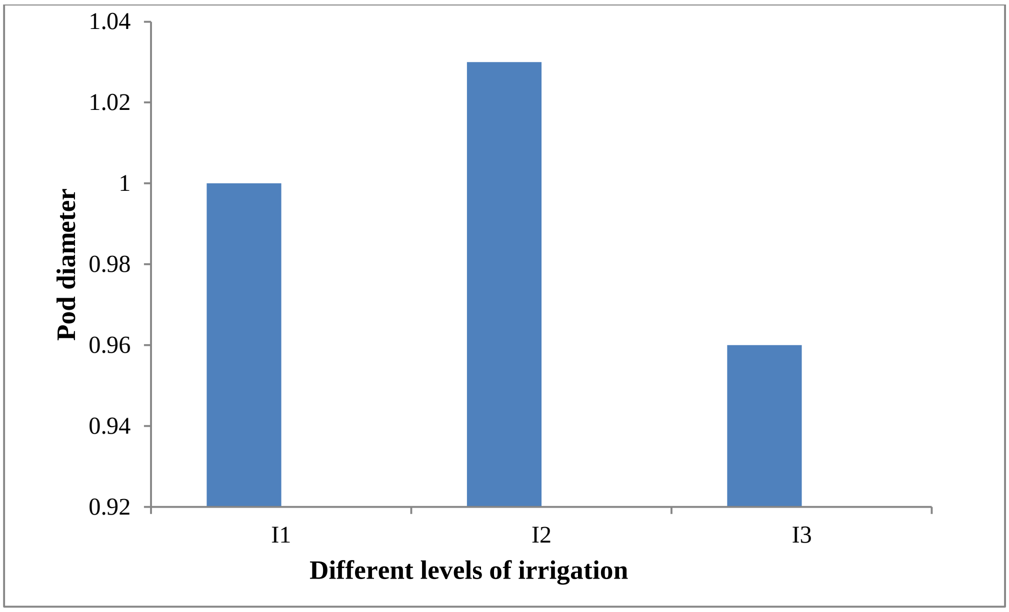

Fig.19. Effect of irrigation frequency on pod diameter of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Significant influence was noted on pod diameter influenced by combined effect of nutrient sources and irrigation frequency (Table 7). The highest pod diameter (1.06 cm) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_2I_2, F_3I_2 and F_4I_1. The lowest pod diameter (0.83 cm) was recorded from the treatment combination of F_1I_3. The treatment combination of F_1I_1 and F_1I_2 also showed comparatively lower pod diameter.

Table 7. Combined effect of nutrient sources and irrigation frequency on number of pods, pod length and pod diameter of French bean

Treatments	Number of pods plant^{-1}	Pod length (cm)	Pod diameter (cm)
F_1I_1	19.86 k	10.32 k	0.94 i
F_1I_2	20.50 h	10.67 j	0.97 h
F_1I_3	18.96 l	9.86 l	0.83 j
F_2I_1	21.36 f	11.32 f	1.03 c
F_2I_2	23.34 c	12.16 c	1.04 b
F_2I_3	19.90 j	11.21 g	1.00 f
F_3I_1	20.28 i	11.46 e	1.02 cd
F_3I_2	22.34 e	12.25 b	1.04 b
F_3I_3	20.81 g	11.15 h	1.01 de
F_4I_1	23.40 b	11.83 d	1.03 b
F_4I_2	24.81 a	13.22 a	1.06 a
F_4I_3	22.41 d	10.83 i	0.98 g
SE (±)	0.29	0.149	0.01
Significant level	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

4.3 Yield parameters

4.3.1 Individual pod weight

Different nutrient sources had significant influence on individual pod weight of French bean (Fig. 20). The highest individual pod weight (12.24 g) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) which was significantly similar with the treatment F_3 (Vermicompost @ 10 t ha^{-1}) where the lowest individual pod weight (10.29 g) was found from the treatment F_1 (Control) followed by the treatment F_2 (N_{60}+P_{20}+K_{30}). Similar result was also observed by Singh *et al*. (2009). Ullah *et al*. (2008) also found similar result with brinjal.

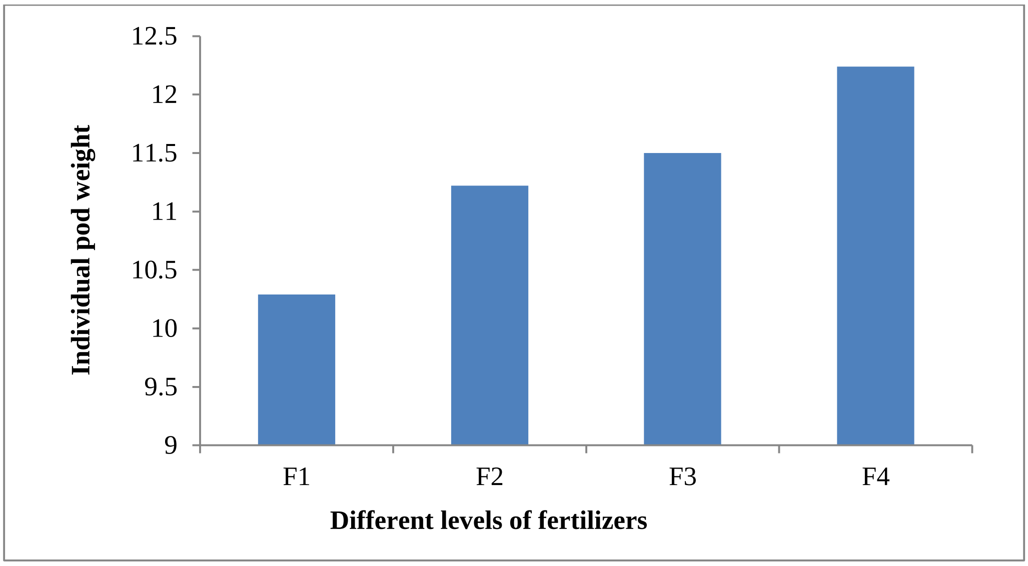

Fig. 20. Effect of nutrient sources on individual pod weight of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

There was a significant variation on individual pod weight of French bean influenced by different irrigation levels (Figure 21). It was found that the highest individual pod weight (11.86 g) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was not significantly different from I_1 (3 days interval irrigation) where the lowest individual pod weight (10.38 g) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). The result on individual pod weight was similar with the findings of Khot *et al*. (2008).

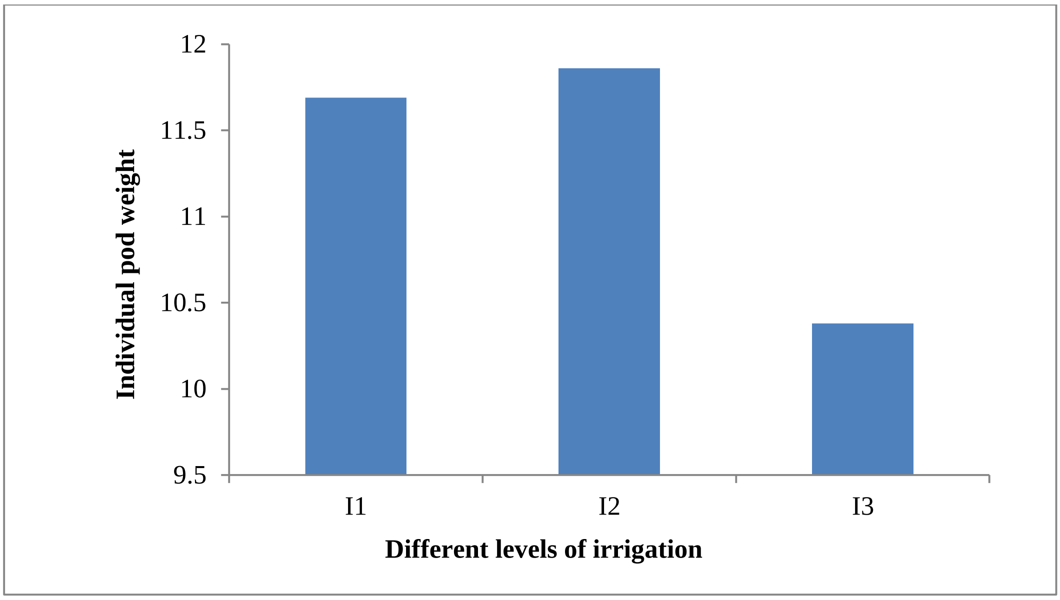

Fig. 21. Effect of irrigation frequency on individual pod weight of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Individual pod weight was significantly influenced by combined effect of nutrients and irrigation frequency at different growth stages (Table 8). It was noticed that the highest individual pod weight (13.78 g) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_4I_1. Similarly, the lowest individual pod weight (10.12 g) was recorded from the treatment combination of F_1I_3 followed by the treatment combination of F_1I_1.

4.3.2 Dry matter content of pod

There was a significant variation on dry weight of pod plant^{-1} influenced by different nutrient sources (Fig. 22). Results signified that the highest dry weight of pod plant^{-1} (12.44 g) was found from the treatment F_3 (Vermicompost @ 10 t ha^{-1}) which was statistically similar with F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}). The lowest dry weight of pod plant^{-1} (10.67 g) was found from the treatment F_1 (Control) which was statistically identical with F_2 (N_{60}+P_{20}+K_{30}). Singh *et al*. (2011) also investigated similar result.

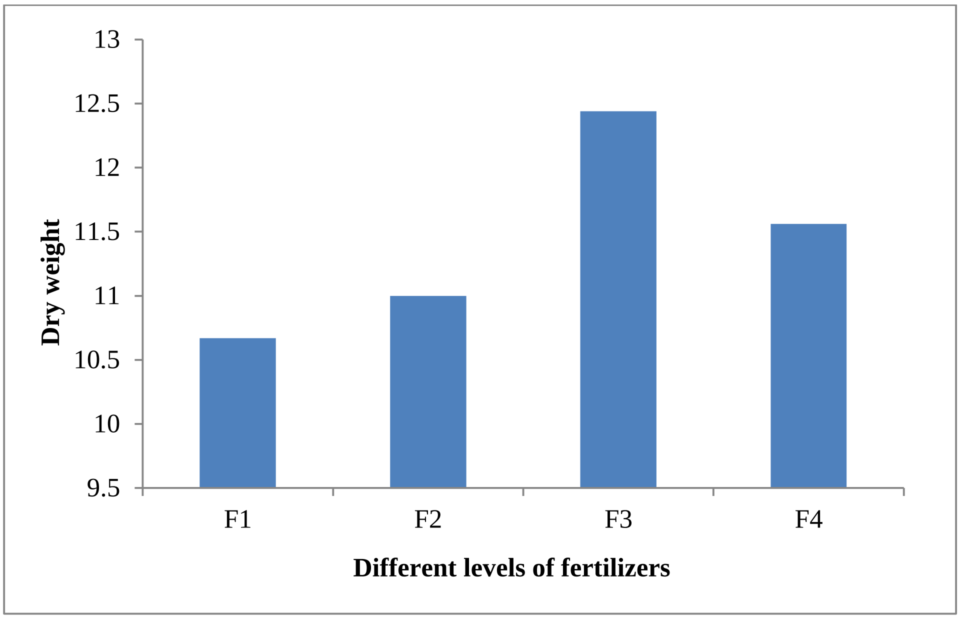

Fig.22. Effect of nutrient sources on dry matter content of pod of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Significant variation was not found for dry weight of pod plant^{-1} influenced by different irrigation levels (Fig. 23). But the highest dry weight of pod plant^{-1} (11.83 g) was achieved from the irrigation level I_3 (9 days interval irrigation) and the lowest dry weight of pod plant^{-1} (11.17 g) was achieved from the irrigation treatment of I_2 (6 days interval irrigation). Salter and Goode (1997) and Dubtez and Mahalle (1969) also found similar result.

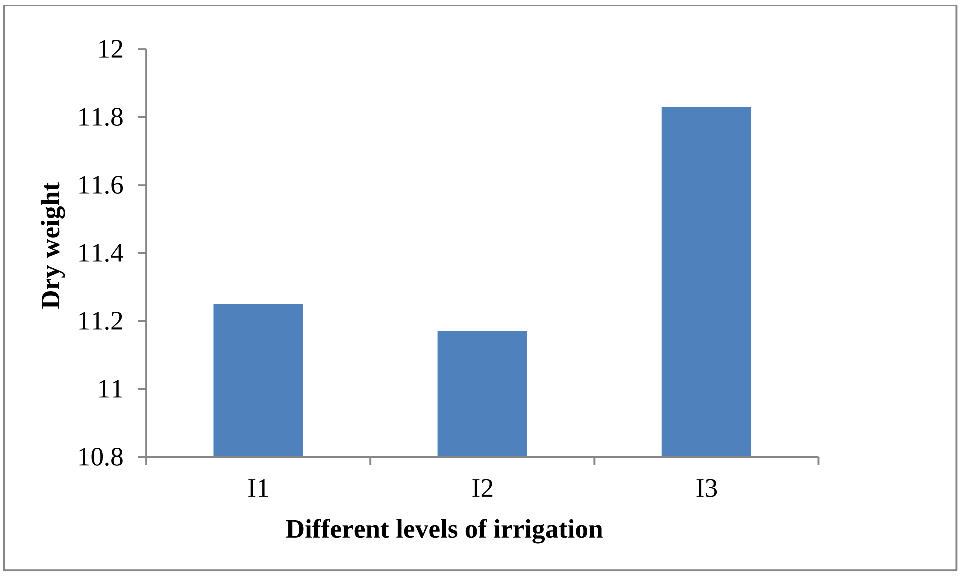

Fig. 23. Effect of irrigation frequency on dry matter content of pod of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Dry weight of pod plant^{-1} was significantly influenced by combined effect of nutrient sources and irrigation frequency (Table 8). It was observed that the highest dry weight of pod plant^{-1} (13.33 g) was recorded from the treatment combination of F_3I_2 which was statistically similar with F_1I_1, F_1I_3, F_2I_1, F_2I_3, F_3I_1, F_3I_3, F_4I_1, F_4I_2 and F_4I_3 where the lowest dry weight of pod plant^{-1} (10.00 g) was recorded from the treatment combination of F_1I_2 which was statistically identical with F_2I_2.

4.3.3 Pod yield plant^{-1}

Significant variation was observed on pod yield plant^{-1} influenced by different nutrient sources (Fig. 24). Results showed that the highest pod yield plant^{-1} (289.48 g) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) followed by the treatment F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}) where the lowest pod yield plant^{-1} (203.65 g) was found from the treatment F_1 (Control). Similar results was also observed by Arya *et al*. (1999) and Gajendra and Singh (1998).

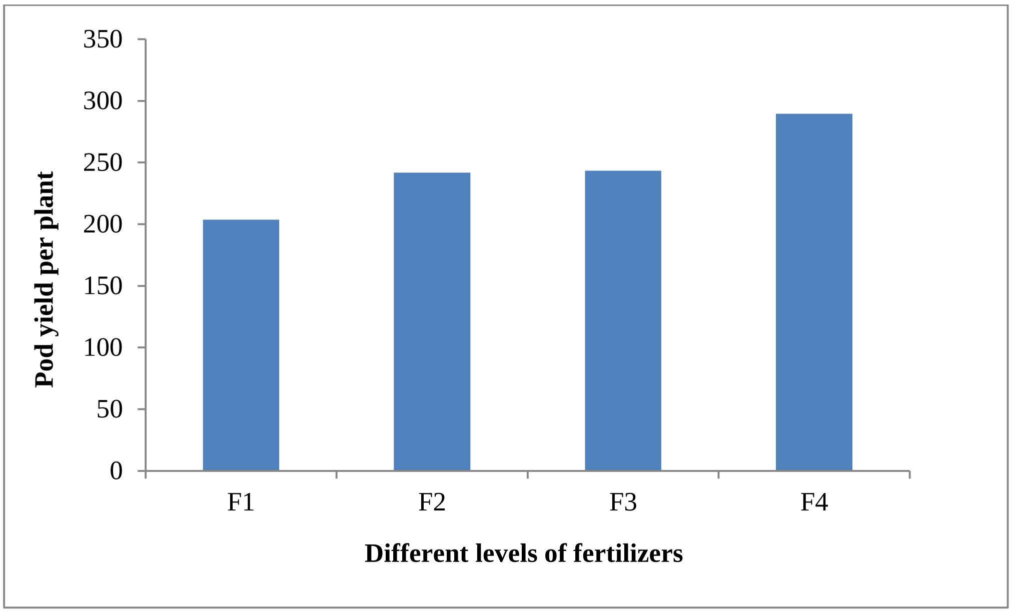

Fig. 24. Effect of nutrient sources on pod yield per plant of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Pod yield $plant^{-1}$ was significantly varied due to different irrigation frequency (Fig. 25). The highest pod yield $plant^{-1}$ (271.53 g) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically same with I_1 (3 days interval irrigation) where the lowest pod yield $plant^{-1}$ (213.14 g) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). The results on pod yield $plant^{-1}$ achieved from the present study were conformity with the findings of Khot *et al*. (2008) and Biswas (2001).

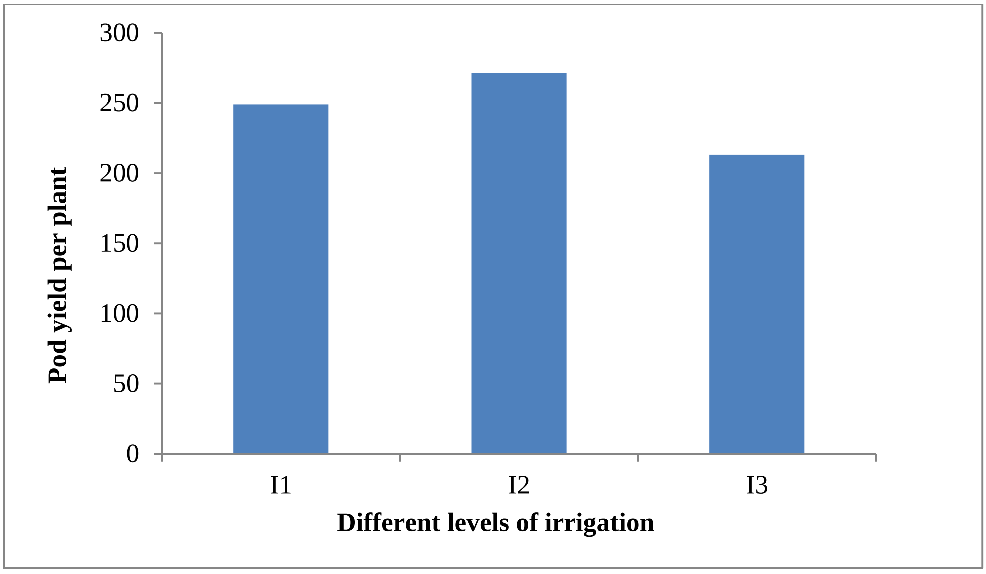

Fig. 25. Effect of irrigation frequency on pod yield per plant of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

Remarkable variation was observed on pod yield plant^{-1} influenced by combined effect of nutrient sources and irrigation frequency (Table 8).Results revealed that the highest pod yield plant^{-1} (341.80 g) was recorded from the treatment combination of F_4I_2 followed by the treatment combination of F_4I_1. The lowest pod yield plant^{-1} (191.84 g) was recorded from the treatment combination of F_1I_3 which was significantly different from other treatment combinations. But the treatment combination of F_1I_1, F_1I_2 and F_3I_3 also showed lower pod yield plant^{-1}.

4.3.4 Pod yield plot^{-1}

Significant influence was noted on pod yield plot^{-1} affected by different nutrient sources (Fig. 26). The highest pod yield plot^{-1} (1042.11 g) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) where the lowest pod yield plot^{-1} (733.15 g) was found from the treatment F_1 (Control). The treatment F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}) showed medium level pod yield plot^{-1} compared to other treatments which were statistically identical with each other. The highest pod yield $plot^{-1}$ from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) might be due to cause of higher pod yield $plant^{-1}$ with the same treatment.

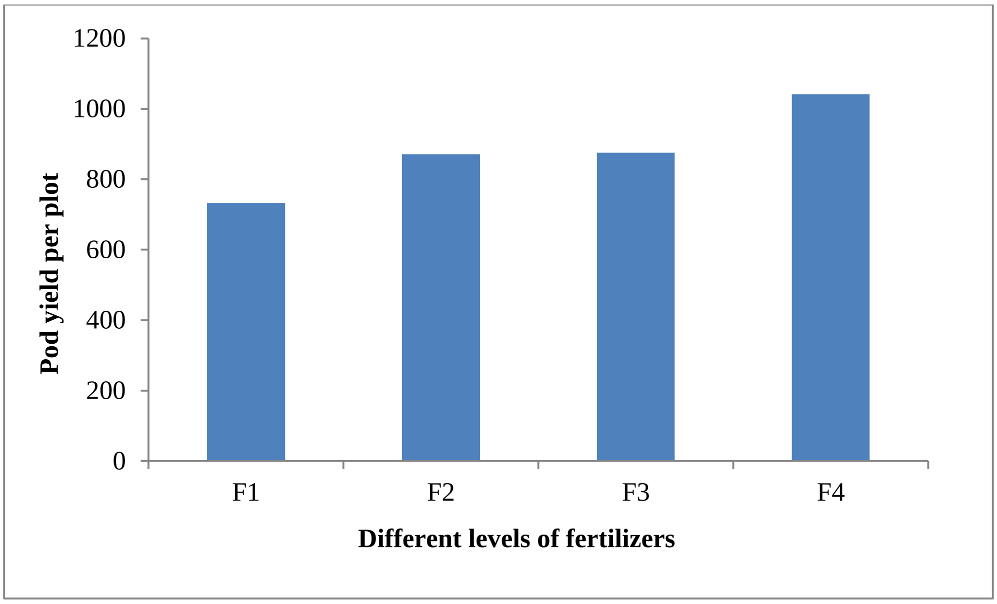

Fig.26. Effect of nutrient sources on pod yield per plot of French bean

F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 ton ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1})

Pod yield $plot^{-1}$ varied significantly due to different irrigation levels (Figure 27). The highest pod yield $plot^{-1}$ (977.53 g) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) where the lowest pod yield $plot^{-1}$ (767.30 g) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). The highest pod yield $plot^{-1}$ from the treatment I_2 (6 days interval irrigation) might be due to cause of higher pod yield $plant^{-1}$ with the same treatment.

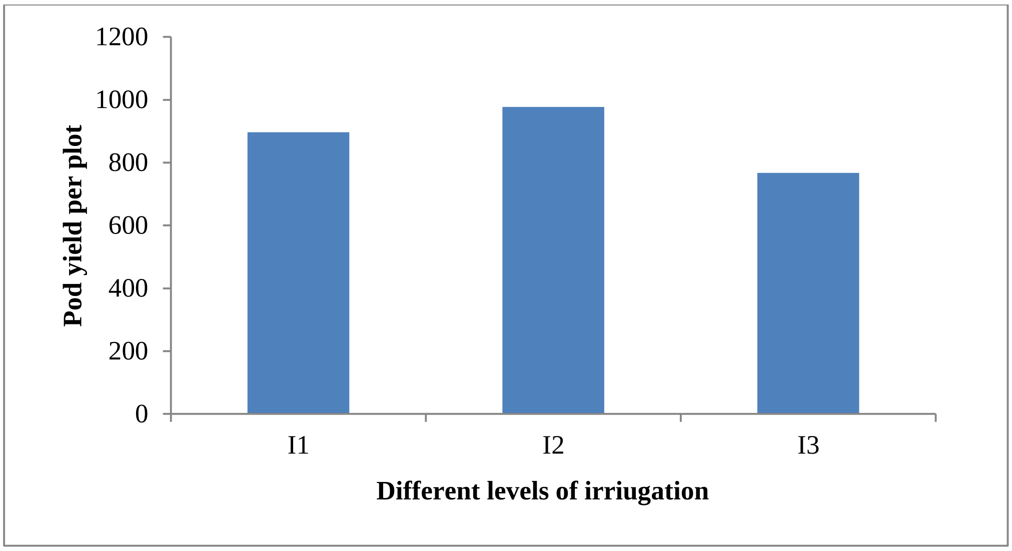

Fig. 27. Effect of irrigation frequency on pod yield per plot of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 day s interval

Significant variation was remarked on pod yield plot^{-1} as influenced by combined effect of nutrient sources and irrigation frequency (Table 8). The highest pod yield plot^{-1} (1230.48 g) was recorded from the treatment combination of F_4I_2 which was significantly different from all other treatment combinations. But the treatment combination of F_4I_1, F_3I_2 and F_2I_2 showed comparatively higher pod yield plot^{-1} compared to others. Similarly, the lowest pod yield plot^{-1} (690.98 g) was recorded from the treatment combination of F_1I_3 which was significantly different from other treatment combinations. But the treatment combination of F_1I_1, F_1I_2, F_2I_3 and F_3I_3 showed comparatively lower pod yield plot^{-1} compared to other treatment combinations.

4.3.5 Pod yield ha^{-1}

Pod yield ha^{-1} was found significant with the application of different nutrient sources (Fig. 28). The highest pod yield ha^{-1} (12.87 t) was found from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}) which was significantly different from others. The results obtained from the treatments F_2 (N_{60}+P_{20}+K_{30}) and F_3 (Vermicompost @ 10 t ha^{-1}) showed medium level pod yield ha^{-1} and significantly same with each other. The lowest pod yield ha^{-1} (9.05 t) was found from the treatment F_1 (Control). The results found from the present study was conformity with findings of Singh *et al*. (2011), Singh *et al*. (2009), Arya *et al*. (1999) and Gajendra and Singh (1998).

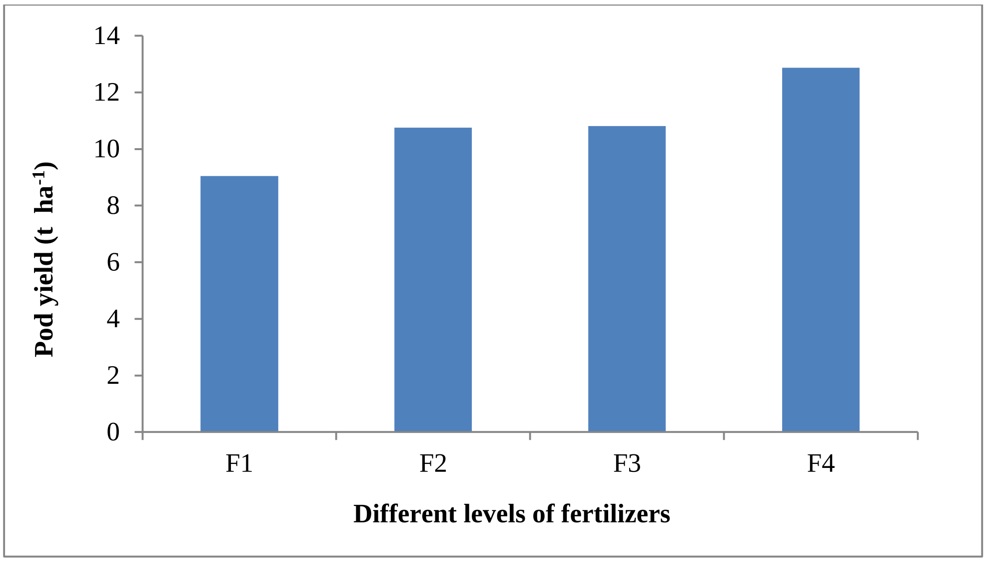

Fig. 28. Effect of nutrient sources on pod yield (t ha^{-1}) of French bean

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Variation on pod yield ha^{-1} was noted as significant influenced by different irrigation levels (Figure 29). The highest pod yield ha^{-1} (12.07 t) was achieved from the irrigation level of I_2 (6 days interval irrigation) which was statistically identical with I_1 (3 days interval irrigation) whereas the lowest pod yield ha^{-1}(9.47 t) was achieved from the irrigation treatment of I_3 (9 days interval irrigation). Similar results on pod yield ha^{-1} were also achieved from the findings of Khot *et al*. (2008), Biswas (2001), Salter and Goode (1997) and Siowit and Kramer (1997).

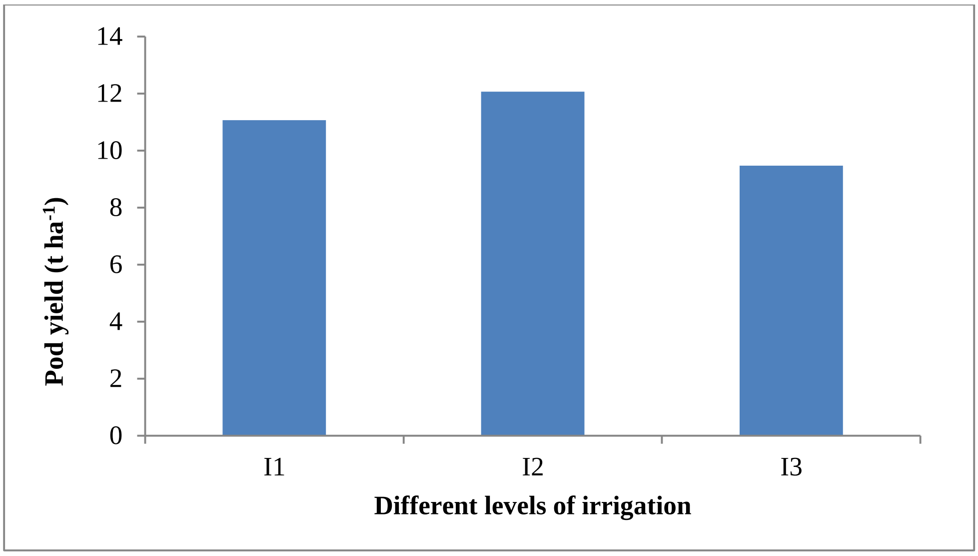

Fig. 29. Effect of irrigation frequency on pod yield (t ha^{-1}) of French bean

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval

The recorded data on pod yield ha^{-1} was significant with the combined effect of nutrient sources and irrigation schedule (Table 8). Results indicated that the highest pod yield ha^{-1} (15.19 t) was recorded from the treatment combination of F_4I_2 where the second highest pod yield ha^{-1} was obtained from the treatment combination of F_4I_1 and next to F_3I_2. The lowest pod yield ha^{-1} (8.53 t) was recorded from the treatment combination of F_1I_3 which was statistically identical with the treatment combination of F_1I_1 and previous lowest yield was from F_1I_2 and F_3I_3.

Table 8: Combined effect of nutrient sources and irrigation frequency on individual pod weight, dry matter content of pod, pod yield per plant, pod yield per plot and pod yield (t ha^{-1}) of French bean

Treatments	Individual pod weight (g)	Dry matter content of pod plant^{-1} (g)	Pod yield plant^{-1} (g)	Pod yield per plot^{-1} (g)	Pod yield (t ha^{-1})
F_1I_1	10.25 j	11.33 ab	203.56 j	732.83 j	9.05 j
F_1I_2	10.51 h	10.00 b	215.45 h	775.64 h	9.58 i
F_1I_3	10.12 k	10.67 ab	191.94 k	690.98 k	8.53 j
F_2I_1	11.62 e	11.33 ab	248.27 f	893.79 f	11.04 f
F_2I_2	11.27 f	10.33 b	263.04 d	946.95 d	11.69 d
F_2I_3	10.76 g	11.33 ab	214.19 i	771.09 i	9.52 h
F_3I_1	12.30 c	11.33 ab	249.51 e	898.24 e	11.09 e
F_3I_2	11.90 d	13.33 a	265.85 c	957.04 c	11.82 c
F_3I_3	10.31 i	12.67 ab	214.48 i	772.13 i	9.53 i
F_4I_1	12.59 b	11.00 ab	294.68 b	1060.86 b	13.10 b
F_4I_2	13.78 a	11.00 ab	341.80 a	1230.48 a	15.19 a
F_4I_3	10.35 i	12.67 ab	231.94 g	834.10 g	10.31g
SE (±)	0.19	0.25	6.92	24.90	0.31
Significant level	0.000	0.200	0.000	0.000	0.000

F_1: 0 (Control), F_2: $N_{60}+P_{20}+K_{30}$, F_3: Vermicompost (10 ton ha^{-1}) and F_4: $N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

I_1: Irrigation at 3 days interval, I_2: Irrigation at 6 days interval and I_3: Irrigation at 9 days interval.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period of November 2016 to March 2017. The experiment consisted of two factors. Factor A: Nutrient sources (four levels) *viz*. F_1: 0 (Control), F_2: N_{60}+P_{20}+K_{30}, F_3: Vermicompost (10 t ha^{-1}) and F_4: N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1}) and Factor B: Irrigation frequency (3 levels) *viz*. I_1: 3 days interval, I_2: 6 days interval and I_3: 9 days interval. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The French bean cultivar BARI Jhar Sheem 1 was used in this experiment collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Data on different growth, yield contributing characters and yield at different days after sowing (DAS) were recorded.

Different nutrient sources treatment showed significant influence for most of the parameters. Considering growth parameters, it was found that the highest plant height (27.43, 37.80 and 46.37 cm at 15, 30 and 45 DAS, respectively), highest number of branches $plant^{-1}$ (1.81, 5.48 and 9.23 at 15, 30 and 45 DAS, respectively), highest number of compound leaves $plant^{-1}$ (3.90, 10.21 and 17.21 at 15, 30 and 45 DAS, respectively), highest leaf length (9.17, 10.01 and 10.78 cm at 15, 30 and 45 DAS, respectively) and highest leaf breadth (7.72, 8.69 and 9.94 cm at 15, 30 and 45 DAS, respectively) were obtained from the treatment F_4 (N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}). Considering yield contributing parameters and yield influenced by nutrient sources, the highest number of flowers $plant^{-1}$ (6.76, 12.17 and 18.87 at 15, 30 and 45 DAS, respectively), highest number of pods $plant^{-1}$ (23.54), highest pod length (11.96 cm), highest pod diameter (1.03 cm), highest individual pod weight (12.24 g), highest pod yield $plant^{-1}$ (289.48 g), highest pod yield $plot^{-1}$ (1042.11 g) and highest pod yield ha^{-1} (12.87 t) were also achieved from the treatment F_4

(N_{30}+P_{10}+K_{15} + Vermicompost @ 5 t ha^{-1}). But the highest dry weight of pod $plant^{-1}$ (12.44 g) was found from the treatment F_3 (Vermicompost @ 10 t ha^{-1}). The lowest plant height (24.81, 31.81 and 38.16 cm at 15, 30 and 45 DAS, respectively), lowest number of branches $plant^{-1}$ (1.13, 4.33 and 7.29 at 15, 30 and 45 DAS, respectively), lowest number of compound leaves $plant^{-1}$ (3.28, 9.27 and 15.03 at 15, 30 and 45 DAS, respectively), lowest leaf length (8.35, 8.76 and 9.42 cm at 15, 30 and 45 DAS, respectively), lowest leaf breadth (7.14, 8.06 and 9.11 cm at 15, 30 and 45 DAS, respectively), lowest number of flowers $plant^{-1}$ (4.32, 8.41 and 13.27 at 15, 30 and 45 DAS, respectively) and lowest number of flowers $plant^{-1}$ (4.32, 8.41 and 13.27 at 15, 30 and 45 DAS, respectively) were found from the treatment F_1 (Control). The lowest number of pods $plant^{-1}$ (19.77), lowest pod length (10.28 cm), lowest pod diameter (0.91 cm), lowest individual pod weight (10.29 g), lowest dry weight of pod $plant^{-1}$ (10.67 g), lowest pod yield $plant^{-1}$ (203.65 g), lowest pod yield $plot^{-1}$ (733.15 g) and lowest pod yield ha^{-1} (9.05 t) were also found from the treatment F_1 (Control)

Different irrigation frequency showed significant variation among the treatments regarding growth, yield contributing parameters and yield of French bean. Considering growth parameters, the highest plant height (28.20, 38.61 and 44.78 cm at 15, 30 and 45 DAS, respectively), highest number of branches $plant^{-1}$ (1.81, 5.65 and 8.97 at 15, 30 and 45 DAS, respectively), highest number of compound leaves $plant^{-1}$ (3.85, 10.38 and 17.46 at 15, 30 and 45 DAS, respectively), highest leaf length (9.20, 9.96 and 10.81 cm at 15, 30 and 45 DAS, respectively) and highest leaf breadth (7.72, 8.71 and 9.94 cm at 15, 30 and 45 DAS, respectively) were achieved from the irrigation level of I_2 (6 days interval irrigation). Considering yield and yield contributing parameters, the highest number of flowers $plant^{-1}$ (6.78, 12.34 and 18.57 at 15, 30 and 45 DAS, respectively), highest number of pods $plant^{-1}$ (22.75), highest pod length (12.08 cm), highest pod diameter (1.03 cm), highest individual pod weight (11.86 g), highest pod yield $plant^{-1}$ (271.53 g), highest pod yield $plot^{-1}$ (977.53 g) and highest pod yield ha^{-1} (12.07 t) were also achieved from the irrigation level of I_2 (6 days interval irrigation). But the highest dry weight of pod plant^{-1} (11.83 g) was achieved from the irrigation level I_3 (9 days interval irrigation). Again, the lowest plant height (23.71, 31.25 and 40.93 cm at 15, 30 and 45 DAS, respectively), lowest number of branches plant^{-1} (1.28, 4.28 and 7.46 at 15, 30 and 45 DAS, respectively), lowest number of compound leaves plant^{-1} (3.55, 9.43 and 15.12 at 15, 30 and 45 DAS, respectively), lowest leaf length (8.55, 9.11 and 9.97 cm at 15, 30 and 45 DAS, respectively), lowest leaf breadth (7.19, 8.12 and 9.27 cm at 15, 30 and 45 DAS, respectively), lowest number of flowers plant^{-1} (5.10, 9.58 and 14.81 at 15, 30 and 45 DAS, respectively) and lowest number of flowers plant^{-1} (5.10, 9.58 and 14.81 at 15, 30 and 45 DAS, respectively) were achieved from the irrigation treatment of I_3 (9 days interval irrigation). The lowest number of pods plant^{-1} (20.52), lowest pod length (10.76 cm), lowest pod diameter (0.96 cm), lowest individual pod weight (10.38 g), lowest pod yield plant^{-1} (213.14 g), lowest pod yield plot^{-1} (767.30 g) and lowest pod yield ha^{-1} (9.47 t) were also achieved from the irrigation treatment of I_3 (9 days interval irrigation). But the lowest dry weight of pod plant^{-1} (11.17 g) was achieved from the irrigation treatment of I_2 (6 days interval irrigation)

In terms of combined effect of nutrient sources and irrigation frequency, all the studied parameters were influenced significantly. Considering growth parameters, the highest plant height (30.33, 41.83 and 51.43 cm at 15, 30 and 45 DAS, respectively), highest number of branches plant^{-1} (2.10, 6.25 and 10.22 at 15, 30 and 45 DAS, respectively), highest number of compound leaves plant^{-1} (4.10, 11.16 and 19.48 cm at 15, 30 and 45 DAS, respectively), highest leaf length (9.51, 10.61 and 11.45 cm at 15, 30 and 45 DAS, respectively) and highest leaf breadth (8.17, 9.06 and 10.32 cm at 15, 30 and 45 DAS, respectively) were recorded from the treatment combination of F_4I_2. Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (7.81, 14.61and 21.84 at 15, 30 and 45 DAS, respectively), highest number of pods plant^{-1} (24.81), highest pod length (13.22 cm), highest pod diameter (1.06 cm), highest individual pod weight (13.78 g), highest pod yield plant^{-1} (341.80

g), highest pod yield plot^{-1} (1230.48 g) and highest pod yield ha^{-1} (15.19 t) were recorded from the treatment combination of F_4I_2 but the highest dry weight of pod plant^{-1} (13.33 g) was recorded from the treatment combination of F_3I_2. Again, the lowest plant height (21.53, 28.60 and 36.65 cm at 15, 30 and 45 DAS, respectively), lowest number of branches plant^{-1} (0.98, 3.91 and 6.77 at 15, 30 and 45 DAS, respectively), lowest number of compound leaves plant^{-1} (3.03, 8.92 and 14.21 cm at 15, 30 and 45 DAS, respectively), lowest leaf length (7.63, 7.83 and 8.83 cm at 15, 30 and 45 DAS, respectively), lowest leaf breadth (6.66, 7.48 and 8.68 cm at 15, 30 and 45 DAS, respectively), lowest number of flowers plant^{-1} (4.03, 8.20 and 12.82 at 15, 30 and 45 DAS, respectively) and lowest number of flowers plant^{-1} (4.03, 8.20 and 12.82 at 15, 30 and 45 DAS, respectively) was recorded from the treatment combination of F_1I_3. The lowest number of pods plant^{-1} (18.96), lowest pod length (9.86 cm), lowest pod diameter (0.83 cm), lowest individual pod weight (10.12 g), lowest pod yield plant^{-1} (191.84 g), lowest pod yield plot^{-1} (690.98 g) and lowest pod yield ha^{-1} (8.53 t) were also recorded from the treatment combination of F_1I_3. But the lowest dry weight of pod plant^{-1} (10.00 g) was recorded from the treatment combination of F_1I_2.

Conclusion

Based on the results of the present study, the following conclusions may be drawn-

1. The nutrient application through N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1}) (F_4) treatment showed maximum yield and yield parameters of French bean compared to other fertilizer treatments.
2. The irrigation at 6 days interval (I_2) showed best yield returns compared to other studied treatments
3. The treatment combination of N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1}) with Irrigation at 6 days interval (F_4I_2) performed the best results in terms of pod yield of French bean compared to other treatment combinations.

So, the treatment combination of F_4I_2 [N_{30}+P_{10}+K_{15} + Vermicompost (5 t ha^{-1}) with irrigation at 6 days interval)] can be considered as the suitable treatment combination compared to other treatment combinations for better growth and higher yield of French bean.

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APPENDICES

Appendix I (a). Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	32.45
Silt	61.35
Clay	6.10
Textural class	Sandy loam

Chemical analysis

Soil properties	Amount
Soil pH	5.5
Organic carbon (%)	1.32
Total nitrogen (%)	0.075
Available P (ppm)	19.5
Exchangeable K (%)	0.2

Appendix I (b). Monthwise average recorded data

Month	*Air temperature (℃)		*Relative Humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2016	25.8	16.0	78	00	6.8
December, 2016	22.4	13.5	74	00	6.3
January, 2017	24.5	12.4	68	00	5.7
February, 2017	27.1	16.7	67	30	6.7
March, 2017	31.4	19.6	54	11	8.2

* Monthly average

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka –1212

Appendix II. Analysis of variance of the data on plant height of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of plant height at different days after sowing (DAS)		
		15	30	45
Replications	2	0.46	3.73	1.09
Factor A (Nutrient sources)	3	12.46^{NS}	183.727**	134.186**
Factor B (Irrigation frequency)	2	66.63**	83.727**	61.950**
Interaction A ×B	11	16.76**	52.541**	58.694**
Error	17	1.03	0.98	0.16

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

Appendix III. Analysis of variance of the data on number of branches of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of number of branches at different days after sowing (DAS)		
		15	30	45
Replications	2	0.03	0.32	1.66
Factor A (Nutrient sources)	3	0.80**	2.24**	5.78**
Factor B (Irrigation frequency)	2	0.85**	5.73**	6.88**
Interaction A ×B	11	0.39**	1.87**	3.36**
Error	17	0.08	0.11	0.56

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

Appendix IV. Analysis of variance of the data on number of compound leaves French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of number of compound leaves at different days after sowing (DAS)		
		15	30	45
Replications	2	1.67	1.76	2.17
Factor A (Nutrient sources)	3	0.72**	1.46**	8.49**
Factor B (Irrigation frequency)	2	0.26*	2.83**	16.47**
Interaction A ×B	11	0.26**	1.04**	6.01**
Error	17	0.69	0.76	0.66

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

Appendix V. Analysis of variance of the data on leaf length of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of number of leaf length at different days after sowing (DAS)		
		15	30	45
Replications	2	1.24	2.85	1.87
Factor A (Nutrient sources)	3	1.28**	3.13**	4.59**
Factor B (Irrigation frequency)	2	1.27**	2.43*	2.32*
Interaction A ×B	11	0.67**	1.48**	1.85**
Error	17	1.34	0.82	0.30

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

Appendix VI: Analysis of variance of the data on leaf breadth of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of number of leaf breadth at different days after sowing (DAS)		
		15	30	45
Replications	2	0.14	1.99	1.15
Factor A (Nutrient sources)	3	0.54**	0.65**	1.24**
Factor B (Irrigation frequency)	2	0.84**	1.06**	1.41**
Interaction A ×B	11	0.35**	0.43**	0.64**
Error	17	1.01	0.73	0.28

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

Appendix VII: Analysis of variance of the data on number of flowers of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of number of flowers at different days after sowing (DAS)		
		15	30	45
Replications	2	0.34	4.44	1.89
Factor A (Nutrient sources)	3	11.95**	24.23**	60.13**
Factor B (Irrigation frequency)	2	8.75*	23.99**	42.32*
Interaction A ×B	11	5.14**	12.19**	26.27**
Error	17	2.15	0.68	1.25

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and [NS] Non significant

Appendix VIII: Analysis of variance of the data on number of pods, pod length and pod diameter of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of		
		Number of pods	Pod length	Pod diameter
Replications	2	10.81	0.21	0.06
Factor A (Nutrient sources)	3	21.81**	4.88**	0.03**
Factor B (Irrigation frequency)	2	15.55*	5.31**	0.02*
Interaction A ×B	11	9.32**	2.53**	0.01*
Error	17	0.55	0.46	0.08

**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and [NS] Non significant

Appendix IX: Analysis of variance of the data on individual pod weight, dry weight, pod yield plant$^{-1,}$ pod yield plot^{-1}and yield t ha^{-1} of French bean as influenced by nutrient sources and irrigation frequency.

Source of variation	df	Mean square of				
		Individual pod weight	**Dry weight**	**Pod yield plant^{-1}**	**Pod yield plot^{-1}**	**yield t ha^{-1}**
Replications	2	0.56	0.08	9.32	1.46	0.90
Factor A (Nutrient sources)	3	5.83**	5.44^{NS}	11099.65**	13.18**	13.14**
Factor B (Irrigation frequency)	2	7.85**	1.58^{NS}	10408.63**	8.71**	8.74**
Interaction A ×B	11	3.97**	2.98*	5477.40**	19824.47**	18301.09**
Error	17	0.39	0.82	2.77	0.73	0.24

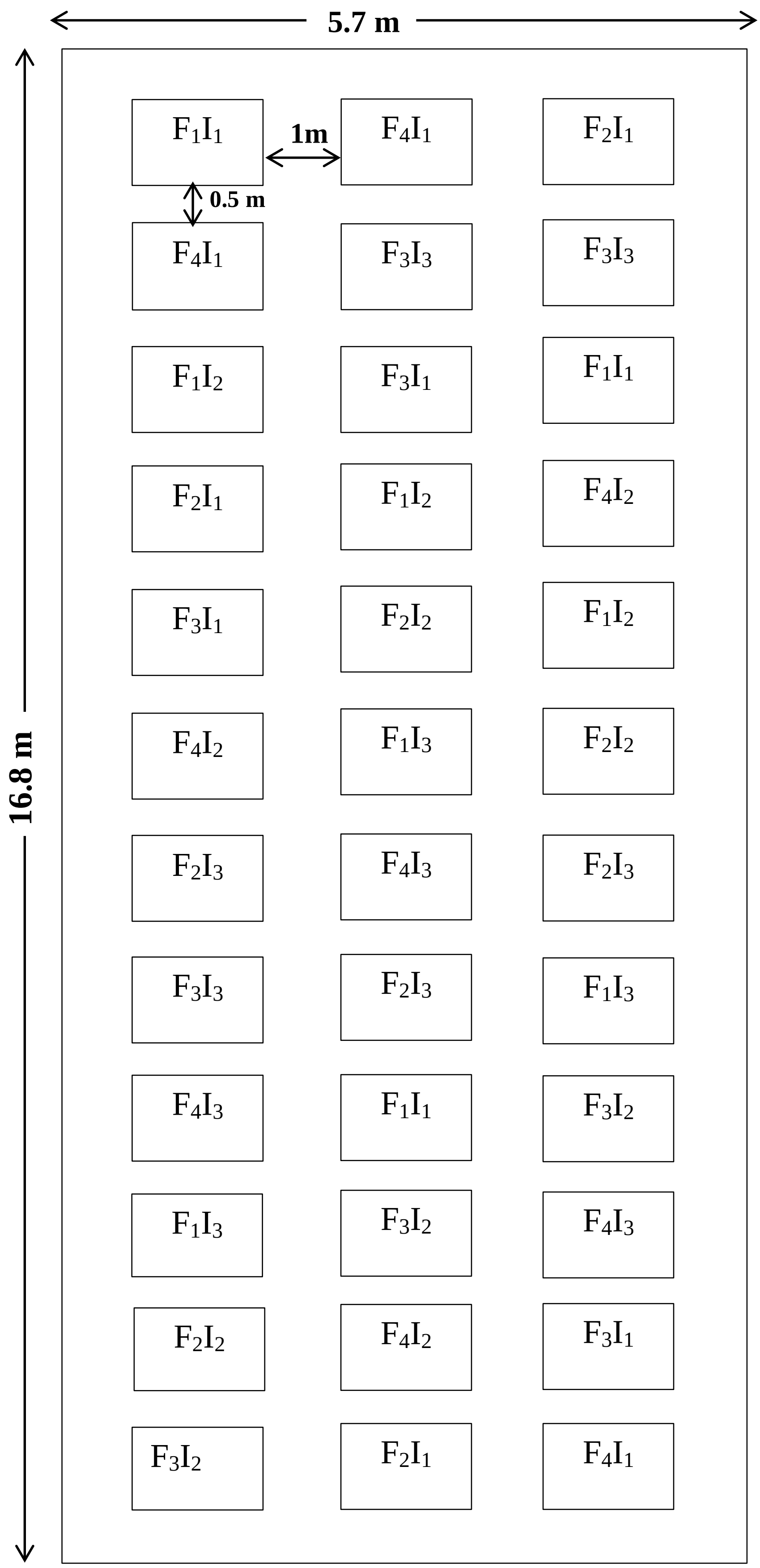
**: Significant at 0.01% level of probability; *: Significant at 0.05% level of probability and ^{NS} Non significant

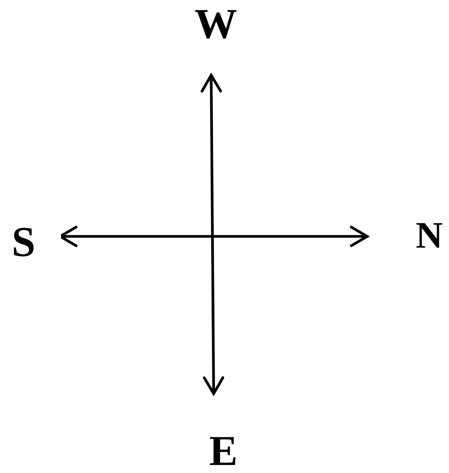
Some pictorial views of experiment

Plate 1. Pictorial presentation of experimental field

Plate 2. An individual plot

Plate 3. A French bean plant with pods





Plot size: 0.9 m × 0.9 m

Block to block distance: 1m

Plot to plot distance: 0.5 m

Factor A: Nutrient sources

F_1= 0 (Control)

$F_2 = N_{60}+P_{20}+K_{30}$

F_3 = Vermicompost (10 ton ha^{-1})

$F_4 = N_{30}+P_{10}+K_{15}$ + Vermicompost (5 t ha^{-1})

Factor B: Irrigation frequency

I_1 = 3 days interval

I_2 = 6 days interval

I_3 = 9 days interval

Fig. 1. Layout of experiment field