



Effect of irrigation regimes and nutrient levels on growth, yield and quality of drip irrigated broad bean (*Vicia faba*)

SANGEETA GUPTA¹, S S KUSHWAH², R K SHARMA³ and O P SINGH⁴

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, College of Horticulture, Mandsaur, Madhya Pradesh 458 001

Received: 22 August 2016; Accepted: 05 June 2017

ABSTRACT

A field experiment was conducted to study the effect of irrigation regimes and nutrient levels on growth, yield, quality, economics and water use efficiency (WUE) of broad bean at College of Horticulture, Mandsaur during *rabi* 2015-16. Treatments included three irrigation regimes, viz. I₁ (IW/CPE=1.00), I₂ (IW/CPE=0.75), I₃ (IW/CPE=0.50) and three nutrient levels, viz. F₁ (15:40:30 kg NPK/ha), F₂ (30:60:45 kg NPK/ha) and F₃ (45:80:60 kg NPK/ha). These treatments were evaluated under split plot design with 6 replications. Results indicated that irrigation level I₁ (IW/CPE=1.00) recorded maximum plant height, number of tillers/plant, number of leaves/plant, leaf area/plant, most delayed 50% flowering and pod maturity, maximum length of pod, number of pod/plant, number of seeds/pod, weight of 10 pods, pod yield/plant, pod yield/hr and fibre content in pod. It was followed by I₂ (IW/CPE=0.75). Highest protein content was found under I₃ (IW/CPE=0.50). WUE decreased with higher irrigation regimes and was observed lowest with I₁ (IW/CPE=1.00). Among nutrient levels, F₃ (45:80:60 kg NPK/ha) registered maximum growth, phenological, yield attributes and yield as well as protein and fibre content. It has also recorded highest WUE. Interactive effect of irrigation regimes and nutrient levels showed highest growth and yield attributes as well as yield with I₁F₃. Highest WUE was recorded with I₃F₂ which was at par to I₃F₃. Maximum gross return (₹ 154 770/ha), net return (₹ 113 820/ha) and benefit:cost ratio (2.77) was obtained with application of I₁F₃.

Key words: Broad bean, Irrigation regimes, Nutrient levels

Broad bean (*Vicia faba* L.) is an important legume vegetable during winter season. It is the fourth most important legume crop in the world after beans, peas and chickpea. Faba bean is an important source of protein for human and animal consumption. The major producers of faba bean are China with 1586 000 MT (31.16% share of production in the world) and Australia with 297 500 MT production (FAO 2013). In India, broad bean is grown on small scale in Uttar Pradesh, Punjab, Haryana, Jammu and Kashmir, Rajasthan, Karnataka, Madhya Pradesh and Bihar (Thamburaj and Singh 2005). The pods of broad bean are used green, generally as cooked vegetable either singly or mixed with potatoes in curry form. It is also used in the preparation of mixed pickle with other vegetables. Boiled seeds of broad bean can also be consumed after applying salt and chilli or black pepper powder.

Water is the most limiting natural resource for agricultural production in arid and semi arid regions. Efficient use of water by irrigation is becoming increasingly

important, and drip irrigation may contribute substantially to the best use of water for agriculture (Sezen *et al.* 2006). Drip irrigation has advantages over conventional systems of irrigation as an efficient means of applying water, especially where water is limited. So water could be saved and both crop quantity and quality could be increased. Balasio *et al.* (2006) studied the response of faba bean to different irrigation intervals (14, 21 and 28 days) on grain yield. They found that the irrigation intervals 28 and 14 days during the vegetative and reproductive stages respectively gave the highest grain yield in the two seasons. In another study it was found that increasing irrigation treatment from 60 to 100% of the ET₀ significantly increased growth, i. e. plant height, number of branches, leaves and pods/plant, leaf area and dry weight of both stem and total plant. A higher water status throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield (Tayel and Sabreen 2011).

One of the major problems that limit economically successful agricultural production worldwide is poor soil fertility. Nutrients play an important role in plant growth. Broad bean is a legume and as such only phosphatic and potassic fertilizers are generally applied. But it is a vigorous legume and makes such rapid growth that often a nitrogenous fertilizer gives a good response. Nutrient depletion of soil is a particular problem for small land

¹Research Scholar (e mail: madhu31gupta@gmail.com),
²Assistant Professor (e mail: kushwahhort@rediffmail.com),
³Assistant Professor (e mail: rksharma3006@gmail.com),
Department of Vegetable Science; ⁴Assistant Professor (e mail: opsingh44@gmail.com), Department of Plant Physiology.

holders in developing countries, where much grain-legume production occurs (Baset and Shamsuddin 2010). Therefore, addition of fertilizers is necessary to correct poor soil fertility by supplying nutrients needed for optimum crop growth. Application of 18-48 kg N/ha and 30-45 kg P/ha stimulated nodulation, enhanced N₂ fixation and produced the highest yield. Response of faba bean to P fertilization is quadratic between 0 and 75 kg P/ha (Tayel and Sabreen 2011). El- Gizawy and Mehasen (2009) found that adding 30 kg P₂O₅/fed mixed with phosphate dissolving bacteria markedly increased plant height, number of branches and pod/plant, 100 seed weight (seed index), seed yield/plant and seed and straw yield/fed. Alderfasi and Alghamdi (2010) reported highest plant vigour with watering up to 75% of water holding capacity in the presence of 100 kg P₂O₅ and 200 kg K₂O/hr. The N-fertilization before sowing improves nodule formation and N-fixation in broad bean (Paolo *et al.* 2015). Keeping the above facts in view, present experiment was conducted to study the effect of irrigation regimes and nutrient levels on growth, yield and quality of broad bean under drip irrigation condition.

MATERIALS AND METHODS

The field experiment was conducted during *rabi* 2015-16 at research field of the Department of Vegetable Science, College of Horticulture, Mandsaur, Madhya Pradesh. Soil of the experimental field was light alluvial having sandy loam texture with low (180 kg/ha) nitrogen, medium (28.2 kg/ha) phosphorus, high (391.9 kg/ha) available potassium, 0.32dS/m electrical conductivity and neutral (pH 7.5) in reaction. Nine treatment combinations comprising of three irrigation regimes, viz. I₁ (IW/CPE=1.00), I₂ (IW/CPE=0.75) and I₃ (IW/CPE=0.50) and three nutrient levels, viz. F₁ (15:40:30 kg NPK/ha), F₂ (30:60:45 kg NPK/ha) and F₃ (45:80:60 kg NPK/ha) were arranged in split plot design with six replications. The main plots were occupied with irrigation regimes and subplots were devoted to nutrient levels.

The land was prepared by deep ploughing, harrowing and levelling and thereafter, beds of 90 cm width and 30 cm high from ground level were prepared. The calculated quantities of fertilizers were applied to the respective plot. The source of nutrients were nitrogen (DAP, Urea), phosphorus (DAP) and potash (MOP). Full dose nitrogen, phosphorus and potash were applied as basal dose prior to sowing of seeds. Pure and healthy seeds of broad bean variety Pusa Sumeet were sown manually in lines with spacing of 30×15 cm and at about 4-5 cm depth. Irrigation was given on the basis of CPE which was recorded from Pan Evaporimeter installed in the field. During each irrigation, 45 mm water (IW) was applied through drip system. Standard package of practices was followed for rest of the operations to grow the crop. Observations were recorded on growth and yield parameters, pod yield (q/ha), protein and fibre content in fresh pod (%), water use efficiency and economics of different treatments. Protein content in the pods was calculated by multiplying nitrogen concentration (%) by the

factor 6.25 (AOAC 1960). Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour (Snell and Snell 1939). Water use efficiency (q/ha-cm) was determined by dividing total pod yield with total water used (Table 1) by the crop. The data obtained from the investigation were subjected to statistical analysis as advocated by Panse and Sukhatme (1984). The economics of different treatments was worked out on the basis of prices prevailing in the market for various inputs and produce.

RESULTS AND DISCUSSION

Effect of irrigation regimes

There was significant effect of irrigation regimes on all the growth, phenological and yield parameters (Table 2). Among the irrigation levels, I₁ (IW/CPE=1.00) recorded maximum plant height, number of tillers/plant, number of leaves/plant and leaf area/plant. It was followed by I₂ (IW/CPE=0.75). While the minimum values of these growth parameters were recorded under I₃ (IW/CPE=0.50). This increase of growth parameters with frequent irrigation suggested favourable effect of water on growth parameters. Higher plant height, more number of tillers accompanied with more number of leaves resulted in more leaf area with higher irrigation regime. Decrease in the leaf area under low irrigation regimes may be also due to the decrease in leaf water content, which in turn reduces the turgor pressure in leaf cells, thereby inhibiting cell division and elongation. Similar findings were also reported by Al-Suhaibani (2009), Ashraf *et al.* (2011), Attia (2013) and Mekkei (2014).

There was significant effect of irrigation regimes on days to 50% flowering. Each increase in irrigation regime showed corresponding delay in flowering. I₃ (IW/CPE=0.50) recorded the earliest 50% flowering followed by I₂ (IW/CPE=0.75). The most delayed 50% flowering

Table 1 Total water used (cm) by the crop under different treatments

Treatment	No. of irrigation	Depth of irrigation (cm)	Water provided through irrigation	Effective rainfall (cm)	Moisture depletion depth of water (cm)	Total water used (cm)
I ₁ F ₁	5	4.5	22.5	0.23	1.69	24.42
I ₁ F ₂	5	4.5	22.5	0.23	2.06	24.79
I ₁ F ₃	5	4.5	22.5	0.23	2.25	24.98
I ₂ F ₁	3	4.5	13.5	0.23	3.31	17.04
I ₂ F ₂	3	4.5	13.5	0.23	3.50	17.23
I ₂ F ₃	3	4.5	13.5	0.23	3.69	17.42
I ₃ F ₁	2	4.5	9.0	0.23	3.81	13.04
I ₃ F ₂	2	4.5	9.0	0.23	3.94	13.17
I ₃ F ₃	2	4.5	9.0	0.23	4.06	13.29

Table 2 Effect of irrigation regimes and nutrient levels on growth parameters of broad bean

Treatment	Growth parameters				Phenological parameters		Yield parameters and yield					
	Plant height (cm)	No. of leaves	Leaf area (cm ²)	No. of tillers	Days taken for 50% flowering	Days taken for 50% maturity	Number of pod/plant	Number of seed/pod	Length of pod (cm) at edible stage	Weight of 10 pods (g)	Pod yield/plant (g)	Pod yield (q/ha)
<i>Irrigation level (I)</i>												
I ₁	59.17	60.58	497.09	4.08	53.58	77.92	33.02	4.38	5.31	19.73	63.67	139.64
I ₂	50.67	55.61	462.66	3.71	52.39	76.32	29.37	3.54	4.42	17.79	54.58	121.21
I ₃	46.19	50.48	437.61	3.34	51.36	74.03	25.06	2.99	3.88	15.99	44.19	104.23
SEm ±	1.39	1.22	7.64	0.09	0.48	0.92	0.60	0.09	0.11	0.37	1.05	2.53
CD (P=0.05)	4.40	3.84	24.08	0.30	1.54	2.92	1.89	0.30	0.35	1.16	3.31	7.98
<i>Nutrient levels (F)</i>												
F ₁	48.02	51.29	434.80	3.34	50.79	74.21	24.87	3.18	4.11	15.73	49.17	104.29
F ₂	52.28	55.57	468.15	3.71	52.73	76.46	30.53	3.77	4.62	18.29	55.57	127.44
F ₃	55.74	59.81	493.42	4.08	53.81	77.61	32.04	3.97	4.88	19.51	57.69	133.35
SEm ±	1.00	1.08	5.48	0.08	0.81	0.89	0.62	0.08	0.08	0.32	1.16	2.59
CD (P=0.05)	2.90	3.12	15.84	0.24	2.35	2.59	1.80	0.24	0.25	0.93	3.37	7.49
<i>Interaction (I × F)</i>												
I ₁ F ₁	51.77	53.94	449.65	3.47	51.47	75.51	28.44	3.81	4.67	16.77	55.01	124.81
I ₁ F ₂	59.26	59.04	497.09	4.01	54.12	78.82	32.84	4.34	5.32	20.37	64.99	139.34
I ₁ F ₃	66.49	68.77	544.57	4.76	55.16	79.44	37.77	5.01	5.94	22.07	70.99	154.77
I ₂ F ₁	48.17	53.21	441.34	3.41	51.07	74.81	25.51	3.14	3.97	15.92	50.66	108.25
I ₂ F ₂	50.44	55.49	467.57	3.81	52.24	76.34	30.42	3.66	4.47	17.56	55.99	123.84
I ₂ F ₃	53.41	58.14	479.06	3.91	53.87	77.81	32.17	3.84	4.81	19.92	57.09	131.56
I ₃ F ₁	44.11	46.74	413.43	3.14	49.82	72.31	20.67	2.61	3.69	14.49	41.84	79.84
I ₃ F ₂	47.14	52.17	439.80	3.31	51.84	74.21	28.34	3.31	4.06	16.94	45.73	119.14
I ₃ F ₃	47.32	52.52	456.62	3.59	52.41	75.57	26.17	3.07	3.91	16.54	45.01	113.72
SEm ±	1.74	1.87	9.50	0.14	1.41	1.55	1.08	0.14	0.15	0.56	2.02	4.49
CD (P=0.05)	5.03	5.41	27.44	0.43	NS	NS	3.13	0.42	0.43	1.61	5.85	12.97

was recorded with I₁ (IW/CPE=1.00). It is possible that more water application leading to higher plant water status might have continued vegetative growth and delayed the flowering and physiological maturity. Similarly, there was linear increase in number of days to 50% pod maturity with each increase in irrigation regime. Irrigation regime I₃ (IW/CPE=0.50) recorded the earliest 50% pod maturity followed by I₂ (IW/CPE=0.75). The most delayed 50% pod maturity was recorded under I₁ (IW/CPE=1.00). It is noticed that plant under water stress condition tried to escape from unfavourable condition by ending their life few days earlier than those under normal soil moisture conditions. Similar findings were reported by Al-Suhaibani (2009).

Irrigation regime I₁ (IW/CPE=1.00) recorded the maximum length of pod, number of pods/plant, number of seeds/pod, weight of 10 pods, pod yield/plant and pod yield/ha. It was followed by I₂ (IW/CPE=0.75). While the minimum length of pod, number of pod/plant, number of seeds/pod, weight of 10 pods, pod yield/plant and pod yield/

ha was found under the irrigation level I₃ (IW/CPE=0.50). Higher growth under higher irrigation regimes might have enhanced the photosynthesis resulting in more synthesis and accumulation of food material which in turn contributed to higher yield attributes and yield. These results were agreement with Singh *et al.* (2001), Al-Suhaibani (2009), Tayal and Sabreen (2011), Attia (2013), Mekkei (2014) and Kumar and Singh (2014).

Among the irrigation levels, highest protein content was found under the irrigation level I₃ (IW/CPE=0.50). It was followed by I₂ (IW/CPE=0.75). While the lowest protein content was found under the irrigation level I₁ (IW/CPE=1.00). These findings could be supported with the results of Al-Suhaibani (2009).

Among the irrigation levels, maximum fibre content was recorded under the irrigation level I₁ (IW/CPE=1.00). It was followed by I₂ (IW/CPE=0.75). While the lowest fibre content was found under the irrigation level I₃ (IW/CPE=0.50).

Effect of nutrient levels

Nutrient levels have indicated significant effect on growth, phenological and yield parameters as well as yield (Table 1). Application of F_3 (45:80:60 kg NPK/ha) has registered maximum plant height, number of tillers/plant, number of leaves and leaf area/plant. It was followed by F_2 (30:60:45 kg NPK/ha). While the minimum plant height was recorded in case of F_1 (15:40:30 kg NPK/ha). These findings were in agreement with those reported by Kadam *et al.* (2009), Shubhashree *et al.* (2011), Hashemabadi (2013), Lad *et al.* (2014) and Shahid *et al.* (2015).

Phenological parameters, viz. days to 50% flowering and days to 50% pod maturity showed significant influence of nutrient levels. There was increase in days to 50% flowering with each increasing level of nutrients. Application of F_1 (15:40:30 kg NPK/ha) recorded earliest 50% flowering followed by F_2 (30:60:45 kg NPK/ha). While the most delayed 50% flowering was recorded under the F_3 (45:80:60 kg NPK/ha). Similar effect of nutrient levels was also reflected in days to 50% pod maturity. Application of nutrient level F_1 (15:40:30 kg NPK/ha) recorded earliest 50% pod maturity followed by F_2 (30:60:45 kg NPK/ha). Maximum days to 50% pod maturity were taken under the application of F_3 (45:80:60 kg NPK/ha). Higher level of nutrients particularly nitrogen might have increased vegetative growth period thereby delayed flowering and which ultimately resulted in late pod maturity. These results corroborated with those reported by Gopal *et al.* (2015).

There was significant effect of nutrient levels on all the yield parameters and yield. Highest pod length, number of pods/plant, number of seeds/pod, weight of 10 pods, pod yield/plant, pod yield/ha was recorded under F_3 (45:80:60 kg NPK/ha). It was followed by F_2 (30:60:45 kg NPK/ha). While the lowest pod length, number of pod/plant, number of seeds/pod, weight of 10 pods, pod yield/plant, pod yield/ha was observed under the nutrient level F_1 (15:40:30 kg NPK/ha). Higher nutrient levels might have enhanced the manufacturing and storage of photosynthates which attributed to higher growth and yield parameters and consequently in higher yield. These findings were in line with Akhtar *et al.* (2003), Kadam *et al.* (2009), Attar *et al.* (2013), Lad *et al.* (2014), Gopal *et al.* (2015) and Shahid *et al.* (2015).

Nutrient levels had exerted significant effect on protein content. Maximum protein content was determined under F_3 (45:80:60 kg NPK/ha). It was followed by F_2 (30:60:45 kg NPK/ha). While the lowest protein content was recorded under the nutrient level F_1 (15:40:30 kg NPK/ha). These results were in agreement with Luikham *et al.* (2009) and Hashemabadi (2013).

There was significant effect of nutrient levels on fibre content. Maximum fibre content was observed under F_3 (45:80:60 kg NPK/ha). It was followed by F_2 (30:60:45 kg NPK/ha). While the lowest fibre content was found under the nutrient level F_1 (15:40:30 kg NPK/ha). Similar results were reported by Ayub *et al.* (2011).

Interaction effect

Combined effect of irrigation regimes and nutrient levels showed significant effect on plant height, number of tillers per plant, number of leaves, leaf area per plant. Highest plant height, number of tillers per plant, number of leaves, leaf area per plant was recorded with I_1F_3 . It was followed by I_1F_2 , I_2F_3 , I_2F_2 in descending order. While lowest plant height, number of tillers per plant, number of leaves, leaf area per plant was found in case of I_3F_1 . Higher moisture availability coupled with higher nutrients might have promoted more food accumulation and thereby enhanced the growth parameters as reflected in the present findings. These findings were in agreement with those reported by Alderfasi and Alghamdi (2010).

Combined effect of irrigation regimes and nutrient levels had registered non significant effect on days to 50% flowering and pod maturity.

Yield attributes and yield were influenced significantly with combined effect of irrigation regimes and nutrient levels. Maximum length of pod, number of pod per plant, number of seeds per pod, weight of 10 pods, pod yield/plant and pod yield per hectare were recorded with treatment combination I_1F_3 which was significantly superior over all other treatment combinations. It was followed by I_1F_2 , I_2F_3 , I_2F_2 , I_3F_2 in descending order. While the minimum length of pod, number of pods/plant, number of seeds/pod, weight of 10 pods, pod yield/plant and pod yield/ha was recorded with treatment combination I_3F_1 . Higher irrigation regimes in combination of higher nutrients might have increased plant growth attributes due to more photosynthesis and assimilation of carbon which ultimately contributed to greater yield parameters and yield.

Combined effect of irrigation regimes and nutrient levels revealed statistically non-significant influence on protein content and fibre content in broad bean pods.

Water use efficiency

Water use efficiency decreased with higher irrigation regimes and lowest water use efficiency was registered with I_1 (IW/CPE=1.00). It was followed by I_2 (IW/CPE=0.75) and I_3 (IW/CPE=0.50) in ascending order. This might be due to fact that the increase in yield was not proportionate to the increase in consumptive use of water. These results corroborated with the findings of Chaudhari *et al.* (2008) and Al-Suhaibani (2009).

Among the nutrient levels, maximum water use efficiency was recorded with F_3 (45:80:60 kg NPK/ha). It was followed by F_2 (30:60:45 kg NPK/ha). While the lowest water use efficiency was recorded with F_1 (15:40:30 kg NPK/ha). Higher nutrient availability enhanced the growth and yield which ultimately increased the water use efficiency. These findings were in agreement to the results obtained by Gopal *et al.* (2015).

Interaction effect of irrigation regime and nutrient levels had showed significant influence on water use efficiency. There was significant increase in water use efficiency at each irrigation regime with increase in nutrient level upto

Table 3 Effect of irrigation regimes and nutrient levels on quality parameters, water use efficiency and economics of broad bean

Treatment	Quality parameters		Water use efficiency (q/ha-cm)	Economics			
	Protein content in fresh pod (%)	Fibre content in fresh pod (%)		Total cost of cultivation (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	B:C ratio
<i>Irrigation level (I)</i>							
I ₁ (IW/CPE=1.00)	12.94	8.79	5.64	40 090	139 640	99 550	2.47
I ₂ (IW/CPE=0.75)	13.71	7.75	7.02	39 090	121 217	82 127	2.09
I ₃ (IW/CPE=0.50)	14.34	7.46	7.90	38 090	104 233	66 143	1.73
SEm ±	0.17	0.12	0.13				0.06
CD (P=0.05)	0.55	0.40	0.42				0.20
<i>Nutrient levels (F)</i>							
F ₁	13.41	7.68	5.86	38 230	104 300	66 070	1.71
F ₂	13.53	8.03	7.28	39 090	127 440	88 350	2.25
F ₃	14.05	8.29	7.43	39 950	133 350	93 400	2.32
SEm ±	0.16	0.10	0.14				0.06
CD (P=0.05)	0.48	0.31	0.40				0.19
<i>Interaction (I × F)</i>							
I ₁ F ₁	12.92	8.42	5.11	39 230	124,810	85 580	2.17
I ₁ F ₂	12.61	8.84	5.62	40 090	139,340	99 250	2.47
I ₁ F ₃	13.28	9.12	6.19	40 950	154,770	113 820	2.77
I ₂ F ₁	13.44	7.42	6.35	38 230	108,250	70 020	1.82
I ₂ F ₂	13.71	7.77	7.18	39 090	123,840	84 750	2.16
I ₂ F ₃	13.97	8.06	7.55	39 950	131,560	91 610	2.28
I ₃ F ₁	13.86	7.21	6.12	37 230	79,840	42 610	1.13
I ₃ F ₂	14.29	7.47	9.04	38 090	119,140	81 050	2.12
I ₃ F ₃	14.89	7.71	8.55	38 950	113,720	74 770	1.91
SEm ±	0.28	0.18	0.24				0.11
CD (P=0.05)	NS	NS	0.70				0.33

F₂. Further increase in nutrient levels under same level of irrigation had imposed non-significant impact on water use efficiency. Though there was decrease in water use efficiency with increasing irrigation regime. Highest water use efficiency was recorded with I₃F₂ which was at par to I₃F₃. These findings might be due to lesser increase in yield as compared to quantity of water under higher irrigation regimes.

Economics of different treatments

The data presented in Table 3 showed that the maximum cost of cultivation was recorded with I₁ irrigation regime. While minimum cost of cultivation was recorded under I₃. Among the nutrient levels, F₃ recorded the highest cost of cultivation followed by F₂. While minimum cost of cultivation was found under the nutrient level F₃. In general, there was increase in cost of cultivation, gross income, net return as well as B:C ratio with higher irrigation regime as well as higher nutrient levels.

Highest cost of cultivation (₹ 40 950/ha), gross income (₹ 154 770/ha) and net return (₹ 113 820) was realized in case of treatment combination I₁F₃. There was significant effect of irrigation regime and nutrient levels on B:C ratio.

Maximum B:C ratio (2.27) was found under I₁F₃ treatment combination followed by I₁F₂, I₂F₃, I₁F₁, I₂F₂ in descending order. While the minimum B:C ratio (1.14) was found with I₃F₁ treatment combination. Higher cost due to higher input and their positive impact on yield resulted in higher gross income, net return as well as B:C ratio. These results were in agreement with Dwivedi *et al.* (2013) in Rajmash.

On the basis of present investigation, it may be concluded that application of I₁ (IW/CPE = 1.00) and nutrient level F₃ (45:80:60 kg NPK/ha) could be advocated for higher yield and realizing maximum gross return, net return and B:C ratio in broad bean.

REFERENCES

- Akhtar Nadeem, Amjad Muhammad and Anjum Muhammad Akbar. 2003. Growth and yield response of pea (*Pisum sativum* L.) crop to phosphorus and potassium application. *Pakistan Journal of Agricultural Sciences* 40(3-4): 217-22.
- Alderfasi AA and Alghamdi S S. 2010. Integrated water supply with nutrient requirements on growth, photosynthesis, productivity, chemical status and seed yield of faba bean. *American Eurasian Journal of Agronomy* 3(1): 8-17.
- Al-Suhaibani N A. 2009. Influence of early water deficit on seed yield and quality of faba bean under arid environment of

- Saudi Arabia. *American Eurasian Journal of Agricultural and Environmental Sciences* 5(5): 649–54.
- Ashraf I, Pervez M A, Amjad M and Ahmad R. 2011. Effect of varying irrigation frequencies on growth, yield and quality of pea seed. *Journal of Agricultural Research* 49(3): 339–53.
- Attar A V, Patil B T, Bhalekar M N and Shinde K G. 2013. Effect of spacing and fertilizer levels on growth, yield and quality of garden pea (*Pisum sativum* L.) cv. Phule Priya. *Bioinfolet* 10(4B): 1240–2.
- Attia M A. 2013. Effect of supplementary irrigation schedules and bio-fertilization on yield and yield attributes of faba bean (*Vicia faba* L.) and lentil (*Lens culinaris* L.) under rainfed conditions. *Alexandria Journal of Agricultural Research* 58(1): 39–46.
- AOAC. 1960. *Official Methods of Analysis*, 8th edn. Association of the Official Analytical Chemists, Washington, DC.
- Ayub M, Khalid M, Tariq M, Nadeem M A and Naeem M. 2011. Effect of different seeding densities and nitrogen levels on growth, forage yield and quality attributes of cluster bean (*Cyamopsis tetragonoloba* Tuab). *Journal of Agricultural Technology* 7(5): 1409–16.
- Balasio E D, Hussein A and Ahmed A. 2006. Effect of watering regimes at two stages of growth on faba bean grain yield at Selain Basin. *Transactions of American Society of Agricultural Engineers* 8: 433–43.
- Baset Mia M A and Shamsuddin Z H. 2010. Rhizobium as a crop enhancer and biofertilizer for increased cereal production. *African Journal of Biotechnology* 9(37): 6001–9.
- Chaudhari S K, Sahu S C, Bardhan Gopali and Khot A B. 2008. Response of french bean (*Phaseolus vulgaris*) to irrigation schedules, phosphorus levels and phosphorus solubilizer in vertisols. *Journal of Agricultural Physics* 8: 1–4.
- Dwivedi V P, Srivastava N K and Yadav V D. 2013. Response of rajmash (*Phaseolus vulgaris* L.) to irrigation and fertilizers. *Indian Journal of Scientific Research* 4(2): 77–9.
- El-Gizawy and Mehasen. 2009. Response of faba bean to bio., mineral phosphorus fertilizers and foliar application with zinc. *World Applied Science Journal* 6(10): 1359–65.
- FAO. 2013. FAOSTAT. Food and Agriculture Organization, Rome. www.fao.org. Accessed on 17/6/2016.
- Gopal Ram, Singh Ghanshyam, Singh A K, Yadav R K, Singh R K and Singh R R. 2015. Effect of moisture regimes and fertility levels on growth and yield of french bean, *Phaseolus vulgaris* under late sown condition. *International Journal of Farm Sciences* 5(2): 53–60.
- Hashemabadi Davood. 2013. Phosphorus fertilizers effect on the yield and yield components of faba bean (*Vicia faba* L.). *Annals of Biological Research* 4(2): 181–4.
- Kadam S B, Maske N M, Linge S S and Pawar S B. 2009. Response of French bean (*Phaseolus vulgaris* L.) to land configurations and fertility levels during *kharif* season. *International Journal of Agricultural Sciences* 5(1): 277–9.
- Kumar Binod and Singh G R. 2014. Response of french bean (*Phaseolus vulgaris* L.) to various sowing methods, irrigation levels and nutrient substitution in relation to its growth, seed yield and nutrient uptake. *Journal of Food Legume* 27(2): 108–11.
- Lad N G, Patange M J and Dhage S J. 2014. Effect of nitrogen and phosphorus levels on growth, yield attributing characters, yield and economics of french bean (*Phaseolus vulgaris* L.). *International Journal of Current Microbiology and Applied Sciences* 3(12): 822–7.
- Luikham E, Phulchand M and Mariam Anal P S. 2009. Response of broad bean (*Vicia faba* L.) to row spacing and phosphorus under late sown rainfed condition of Manipur. *Agriculture Science Digest* 29(1): 54–6.
- Panse V G and Sukhatme P V. 1984. *Statistical Methods for Agricultural Workers*, Fourth Enlarged Edition. ICAR Publication, New Delhi.
- Paolo Elvio Di, Garofalo Pasquale and Rinaldi Michele. 2015. Irrigation and nitrogen fertilization treatments on productive and qualitative traits of broad bean (*Vicia faba* var. minor L.) in a Mediterranean environment. *Legume Research* 38(2): 209–18.
- Mekkei M E I R. 2014. Effect of skipping irrigation at various growth stages on yield and quality of some faba bean cultivars (*Vicia faba* L.). *Journal of Plant Production* 5(7): 1303–5.
- Sezen S M, Yazar A and Eker S. 2006. Effect of drip irrigation regimes on yield and quality of field grown bell pepper. *Agricultural Water Management* 81: 115–31.
- Shahid Muhammad, Malik Ahmad Abbas, Rehman Adil, Khan Muhammad Shirin and Zakaria. 2015. Effect of various levels of nitrogen, phosphorus and potash on the yield of French bean. *Journal of Natural Sciences Research* 5(11): 50–2.
- Shubhashree K S, Alagundagi S C, Hiremath S M, Chittapur B M, Hebsur N S and Patil B C. 2011. Effect of nitrogen, phosphorus and potassium levels on growth, yield and economics of rajmash (*Phaseolus vulgaris*). *Karnataka Journal of Agricultural Sciences* 24(3): 283–5.
- Singh V P, Tripathi S S and Dimri D C. 2001. Effect of irrigation schedule on growth, yield and yield attributes in off season vegetable pea under low hill valley situation of Utranchal. *Vegetable Science* 28(2): 149–51.
- Snell F B and Snell C T. 1939. *Colorimetric Method of Analysis II AD*. Vannostrand Co. Inc. New York.
- Tayel M Y and Sabreen Kh P. 2011. Effect of irrigation regimes and phosphorus level on two *Vicia faba* varieties growth characters. *Journal of Applied Sciences Research* 7(6): 1007–15.
- Thamburaj S and Singh Narendra. 2005. *Textbook of Vegetables, Tuber crops and Spices*, p 219. Indian Council of Agricultural Research, New Delhi.