



Effect of drip irrigation and organic mulches on growth, yield and water-use efficiency of French bean (*Phaseolus vulgaris*)

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Water is crucial for both survival and livelihood, particularly in context to agriculture in India. Efficient water management, by controlled irrigation scheduling is paramount for deficit irrigation management (Kumar *et al.* 2022). Combined use of assured irrigation techniques with *in-situ* moisture conservation methods such as drip irrigation with mulching, can be a viable alternative (Raina *et al.* 2013). It ensures favorable soil moisture regime in the root zone, leading to higher water use efficiency and profitability (Kumar *et al.* 2016). French bean (*Phaseolus vulgaris* L.) is primarily grown for its shelled green and dry beans (Rajmah), tender vegetable and belongs to the family Leguminaceae which are rich in proteins, vitamin A, thiamine, riboflavin, vitamin C and nicotinic acid (Punia *et al.* 2008). In Himachal Pradesh, area under French bean cultivation is about 3820 ha with a production of 50870 MT (Anonymous 2018). As it is a short duration crop, readily available, highly nutritious and is mainly grown during summer season in open field conditions in the mid-hills region of Himachal Pradesh, so by looking into the importance of the crop, to enhance productivity and socio-economic status of farmers, the present study focused on evaluating the impact of irrigation levels and organic mulches on yield and water-use efficiency in drip-irrigated French beans.

A field experiment was conducted during March–July 2021 at the research farm of Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Experiment comprised 7 treatments, i.e. 100% ETc + Grass mulch (I₁M₁); 80% ETc + Grass mulch (I₂M₁); 60% ETc + Grass mulch (I₃M₁); 100% ETc + Pine needle mulch (I₁M₂); 80% ETc + Pine needle mulch (I₂M₂); 60% ETc

+ Pine needle mulch (I₃M₂) and Control-surface irrigation with 4 cm at 10-days interval (I₀M₀) with 3 replications which were laid down in a randomized block design (RBD). Soil of experimental area was sandy clay loam in texture and falls under typic eutrochrept. Recommended doses of nutrients (NPK), i.e. 50:100:50 kg/ha and FYM 100 q/ha were applied as basal dose except N, while the N was applied in two equal split doses, as basal dose and at 30 days after sowing. Results of the physical and hydro-physical properties of soil were like, bulk density (1.28 g/cm³), particle density (2.50 g/cm³), available water (14.25 w/w, %), moisture retention (w/w) at 0.33 bar and 15 bar were 8.09 and 14.25%, respectively. Results of chemical properties were pH (6.76), EC (0.32 ds/m), organic carbon (10.98 g/kg), nitrogen (341.78 kg/ha), phosphorous (56.89 kg/ha) and potassium (257.69 kg/ha) content. Seeds were sown at a spacing of 45 cm × 15 cm in the raised plots of 2.5 m × 2.5 m size. Both mulches of grass mulch as well as pine needle mulch were applied @5 t/ha. After sowing, a 5 mm common irrigation was manually applied daily for 15 days in all plots to ensure good seed germination, followed by subsequent irrigations of various treatments as per irrigation schedules. The meteorological data, i.e. rainfall and pan evaporation for the study area were procured from the meteorological observatory of university. In drip irrigation system, online drippers of 2 lph discharge rate having emitter spacing of 22.5 cm. The depth of irrigation water was multiplied by the plot area to determine the volume of irrigation water needed per plot. The volume of water applied through drip irrigation under different treatments, on a cumulative pan evaporation basis for 100% ETc was computed. Irrigation was applied bi-weekly, i.e. alternatively every three and four days, considering rainfall. Water for surface irrigation was estimated volumetrically per plot. Effective rainfall was calculated using the balance sheet method (Doorenbos and Pruitt 1977). Water requirement was calculated by method given by Michael (2009). Water saving over I₀M₀ was calculated by subtracting the treatment's WR (water

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Table 1 Effect of different irrigation levels and mulches on growth attributes and yield of French bean

| Treatment | Plant height (cm) | Pod diameter (mm) | Pod length (cm) | No. of pods per plant | Days to first harvest | Yield (q/ha) |
|-------------------------------|-------------------|-------------------|-----------------|-----------------------|-----------------------|--------------|
| I ₁ M ₁ | 52.67 | 6.76 | 15.10 | 20.97 | 63.03 | 112.56 |
| I ₂ M ₁ | 53.66 | 6.78 | 15.11 | 22.83 | 61.78 | 118.53 |
| I ₃ M ₁ | 51.26 | 6.91 | 14.23 | 22.12 | 63.74 | 105.34 |
| I ₁ M ₂ | 52.50 | 7.12 | 14.36 | 21.16 | 63.25 | 109.65 |
| I ₂ M ₂ | 51.22 | 7.16 | 14.50 | 21.78 | 62.66 | 111.66 |
| I ₃ M ₂ | 51.31 | 7.12 | 14.62 | 20.65 | 63.70 | 106.26 |
| I ₀ M ₀ | 47.96 | 6.71 | 14.06 | 18.52 | 65.60 | 83.33 |
| CD (P=0.05) | 0.92 | NS | NS | 0.71 | 1.19 | 11.83 |

Refer to the methodology for treatment details.

requirement) from I₀M₀ WR and then divided by I₀M₀ WR. B:C ratio was calculated from gross returns divided by total cost of cultivation. Recorded data were analyzed using MS-Excel, and mean values of data were subjected to analysis of variance (ANOVA) as described by Panse and Sukhatme (2000) by using Randomized Block Design.

Plant growth and yield attributes: Different irrigation levels and mulches did not significantly affect the pod diameter and pod length of French beans. However, the highest pod diameter and pod length was recorded in I₂M₂ and I₂M₁, respectively, while the lowest was in I₀M₀ (Table 1). Plant height and no. of pods per plant were significantly affected by different irrigation levels and mulches. The maximum plant height was recorded in I₂M₁ and the minimum was in I₀M₀ (Table 1). Plant height was higher in 80% ETc irrigation, followed by 100% ETc in both mulches compared to the control, which might be due to weed suppression, adequate availability of moisture and air at optimum soil temperature. This aligns with findings from Saren *et al.* (2008), Gupta *et al.* (2017) and Kader *et al.* (2017).

The maximum no. of pods per plant was recorded in I₂M₂ which was statistically at par with I₃M₁ and the minimum was in I₀M₀ (Table 1). A lower no. of pods per plant was recorded under un-mulched plots with surface irrigation than the mulched ones with drip irrigation. This might be due to lower nutrient losses, better nutrient and

moisture consumption during the flowering stage, and good translocation from source to sink. These results are corroborated by the findings of Kader *et al.* (2017). Significant effect of irrigation levels along with mulches was observed on days to the first harvest, and yield. The shortest days to first harvest occurred in I₂M₁ which was statistically at par with I₂M₂ and the longest were in I₀M₀. The highest yield was recorded in I₂M₂ which was statistically at par with I₁M₁, I₂M₂, I₁M₂, while the lowest yield was in I₀M₀. Optimal soil moisture promotes physiological processes, nutrient uptake, and photosynthesis, resulting in higher yields. Similar findings were reported by Ulyanich *et al.* (2021) and Liu *et al.* (2021).

Water requirement and water-use efficiency: The initial soil moisture content experimental farm was 14.68 and 15.20% at 0–7.5 and 7.5–15 cm respectively. After harvesting, soil moisture content at 0–7.5 cm soil depth, observed as 22.20, 21.95, 21.47, 21.95, 21.57, 19.00 and 18.42% in I₁M₁, I₂M₁, I₃M₁, I₁M₂, I₂M₂, I₃M₂, and I₀M₀ respectively, while respective values of 22.46, 22.15, 21.65, 22.23, 21.95, 19.36 and 19.16% were recorded at 7.5–15 cm soil depth. The maximum net depth of water applied was 22.00 cm in I₀M₀, maximum water saving was recorded in I₂M₁ over control, i.e. surface irrigation and no mulch (Table 2). The maximum yield and maximum water saving were noted in I₂M₁, i.e. 80% ETc with grass mulch. On average, mulched treatment with deficit irrigation achieved around

Table 2 Total water requirement, water saving (%) and water-use efficiency in French bean

| Treatment | Net depth of water applied (cm) | Effective rainfall (cm) | Increase in soil moisture storage (cm) | Total water requirement (cm) | Water saving over I ₀ M ₀ (%) | Water use efficiency (q/ha/cm) |
|-------------------------------|---------------------------------|-------------------------|--|------------------------------|---|--------------------------------|
| I ₁ M ₁ | 16.88 | 13.99 | 2.24 | 28.63 | 24.46 | 3.93 |
| I ₂ M ₁ | 14.63 | 15.60 | 2.18 | 28.05 | 26.00 | 4.23 |
| I ₃ M ₁ | 12.37 | 18.38 | 2.09 | 28.66 | 24.37 | 3.68 |
| I ₁ M ₂ | 16.88 | 13.99 | 2.19 | 28.68 | 24.33 | 3.82 |
| I ₂ M ₂ | 14.63 | 15.60 | 2.13 | 28.10 | 25.87 | 3.97 |
| I ₃ M ₂ | 12.37 | 18.38 | 2.01 | 28.74 | 24.16 | 3.70 |
| I ₀ M ₀ | 22.00 | 17.46 | 1.56 | 37.90 | | 2.20 |

Refer to the methodology for treatment details.

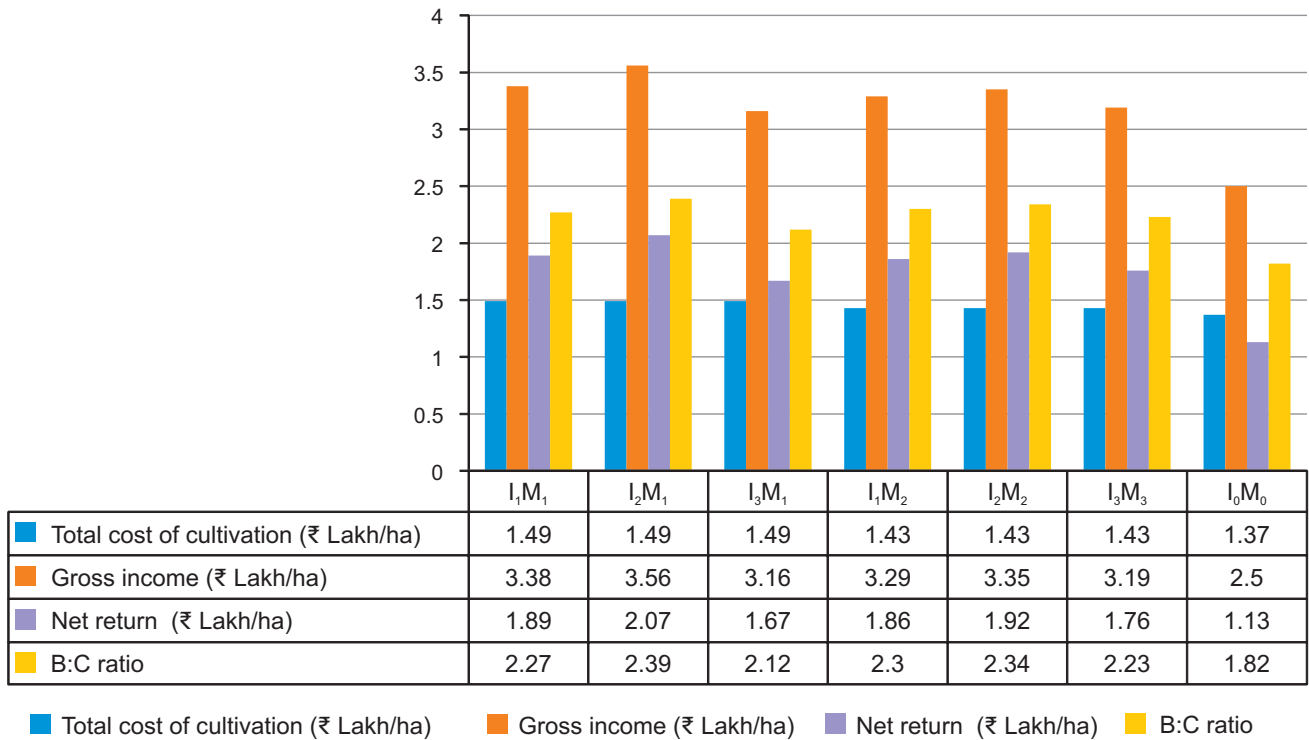


Fig 1 Total cost of cultivation, net returns and B:C ratio for French bean.

24.8% water saving. This approach can help in optimizing water usage in agriculture, potentially expanding irrigated areas and increasing yield per unit area. Significant variations in water-use efficiency for French beans were observed (Table 2). The highest water-use efficiency was found in I₂M₁ and lowest was in I₀M₀. Overall, the average water use efficiency of all treatments with drip irrigation along with mulching was 76.74% higher over control (surface irrigation). Drip irrigation with mulching reduces water loss, enhancing water usage efficiency. Lower drip levels show higher water use efficiency than higher levels. Similar results were found in conformity with Fasina *et al.* (2021) and Liu *et al.* (2021).

Cost economics: Fig 1 represents the economic analysis, including the total cost of cultivation, gross returns, net return, and benefit-cost ratio. The highest gross income was achieved in I₂M₁, followed by I₁M₁, and I₂M₂, while the lowest was observed in I₀M₀. The most economical and cost effective combination was I₂M₁ while the lowest was in I₀M₀. Hence, utilizing drip irrigation at 80% ETc with grass mulch application can maximize French bean yield.

The study suggests that, the irrigation schedule at 80% ETc with Grass mulch (I₂M₁) appears to be the best. The implementation of drip irrigation with mulching resulted in an average water saving of approximately 24.8% and 76.74% higher water-use efficiency compared to control or surface irrigation.

SUMMARY

French bean (*Phaseolus vulgaris* L.) is an important crop for green and dry beans while tender pods as vegetable.

An experiment was conducted during March–June 2021 at the research farm of Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh to assess the effect of different irrigation levels and organic mulches on soil properties, growth and productivity of French bean. Experiment was laid out in Randomized Block Design with 3 replications comprising of 7 treatments. The study resulted, that plant height, no. of pods per plant, days to first harvest and yield of French bean were significantly affected by different irrigation levels and organic mulches. The maximum yield, water use efficiency, B:C ratio were observed under treatment I₁M₂ (80% ETc + Grass mulch). Therefore, adopting drip irrigation with mulching can contribute to increasing irrigated area and enhancing yield potential of French bean in the mid hill zone of Himachal Pradesh.

REFERENCES

- Anonymous. 2018. *Horticultural Statistics at a Glance*. Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmer's Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. pp. 186–87.
- Doorenbos J and Pruitt W O. 1977. Crop water requirements. *FAO irrigation and drainage paper 24*, pp. 144. Land and Water Development Division, FAO, Rome.
- Fasina A S, Shittu O S, Ogunleye K S, Ilori A O and Babalola T S. 2021. Effect of drip irrigation frequency, N-fertilization, and mulching on yield, nitrogen, and water use efficiencies of cucumber (*Cucumis sativus* L.) in Ikole-Ekiti, Nigeria. *Asian Journal of Agriculture and Rural Development* **11**: 184–91.
- Gupta S, Kushwah S S, Sharma R K and Singh O P. 2017. Effect of irrigation regimes and nutrient levels on growth, yield and

- quality of drip irrigated broad bean (*Vicia faba*). *The Indian Journal of Agricultural Sciences* **87**: 50–55.
- Kader M A, Senge M, Mojid M A and Nakamura K. 2017. Mulching type induced soil moisture and temperature regimes and water use efficiency of soybean under rain-fed condition in central Japan. *International Soil and Water Conservation Research* **5**: 302–08.
- Kumar P, Suman S, Spehia R S, Kumar V and Kaith N S. 2016. Studies on method and rate of fertilizer application in apple under mulch in north-western Himalayas. *Journal of Plant Nutrition* **39**(2): 219–26.
- Kumar P, Thakur J and Agrawal G. 2022. Evaluation of regulated deficit drip irrigation strategies in apricot. *Journal of Plant Nutrition* **45**(20): 3109–17.
- Liu Y, Hu C, Li B, Ding D, Zhao Z, Fan T and Li Z. 2021. Subsurface drip irrigation reduces cadmium accumulation of pepper (*Capsicum annuum* L.) plants in upland soil. *The Science of the Total Environment* **755**: 1–10.
- Michael A M. 2009. *Irrigation: Theory and Practice*, 2nd edn, pp. 488. Vikas Publishing House Pvt Ltd.
- Panse V G and Sukhatme P V. 2000. *Statistical Methods for Agricultural Workers*, pp. 378. Indian Council of Agricultural Research, New Delhi, India.
- Punia D, Gupta M, Yadav S K and Khetarpaul N. 2008. Nutrient composition of green beans and their products. *Journal of Indian Dietetic Association* **33**(1): 27–32.
- Raina J N, Suman S, Kumar P and Spehia R S. 2013. Effect of drip fertigation with and without mulch on soil hydrothermal regimes, growth, yield, and quality of apple (*Malus domestica* Borkh). *Communications in Soil Science and Plant Analysis* **44**(17): 2560–70.
- Saren B K, Mandal K and Bag N. 2008. Effect of mulching and row spacing on growth, seed yield and oil yield of rainfed Niger (*Guizotia abyssinica*) in red and lateritic acid belt of West Bengal. *The Indian Journal of Agricultural Sciences* **78**: 557–59.
- Ulyanych O, Poltoretskyi S, Liubych V, Yatsenko A, Yatsenko V, Lazariev O and Kravchenko V. 2021. Effect of surface drip irrigation and cultivars on physiological state and productivity of faba bean crop. *Journal of Agricultural Science* **32**: 139–49.