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Effect of drip fertigation levels on yield and profitability assessment in mid-season Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Abstract
A field trial titled "Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea* var. *botrytis* L.)" was conducted during the *rabi* season of 2018-2019 at the experimental farm of the Water Technology Centre, Indian Agricultural Research Institute, New Delhi. The experiment employed a randomized block design with four treatments: T_1 involved drip fertigation with 100% of the recommended dose of fertilizers as per schedule, T_2 utilized drip fertigation with 75% of the recommended dose, T_3 employed drip irrigation with 100% of conventional fertilizer applied to the soil, and T_4 served as the control with drip irrigation but without fertilizers. Each treatment was replicated five times. The outcomes revealed significant variations in parameters such as fresh curd weight, dry curd weight, net curd weight, and marketable curd weight, with the highest values observed in T_1, where 100% of the recommended fertilizers were used. The cauliflower's curd yield was notably higher in T_1, recording 27.88 tons per hectare. The treatment with 100% recommended dose (T_1) also exhibited the highest benefit-cost ratio at 2.8, emphasizing the economic viability of applying nutrients through drip fertigation to maximize cauliflower growth parameters and yield.

Keywords: Cauliflower, drip fertigation, yield, B:C ratio

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.) stands as a pivotal vegetable crop globally, notably in India, thriving under diverse climatic conditions. Belonging to the Cole crops group, alongside cabbage, Brussel's sprouts, kale, collards, kohlrabi, and broccoli, cauliflower is revered for its delectable taste, flavor, and nutritional richness. Contributing significantly to worldwide vegetable production, it occupies around 2.33% of the total vegetable crop area and contributes approximately 2.36% to global vegetable production (FAOSTAT, 2018) [3]. In India, being the second-largest producer after China, cauliflower production reaches 8.97 million tonnes, covering 4.07 lakh hectares (NHB Database, 2017) [9].

Originally from the Eastern Mediterranean, cauliflower made its way to India in 1822, undergoing genetic changes to adapt to the Indian tropical climate. With distinct temperature requirements during curding, tropical cauliflower is categorized into early, mid-early, and mid-late varieties. 'Pusa Sharad' exemplifies an improved Indian variety suited for cultivation from mid-November to mid-December. However, the cauliflower growing period, spanning September to November, coincides with the receding monsoon, impacting soil nutrient balance due to excess rains causing leaching.

Cauliflower, being a shallow-rooted and irrigation-intensive crop, faces challenges in rain-fed areas. Traditional fertilizer application methods and water scarcity further constrain cauliflower production. Drip irrigation emerges as a promising solution, ensuring uniform head size and high-quality produce. Micro-irrigation practices, particularly drip irrigation and fertigation (application of plant nutrients through irrigation water), offer efficient water usage and nutrient conservation.

Fertigation, especially with water-soluble fertilizers, presents a revolutionary approach to precise and timely crop nutrition. It minimizes leaching and volatilization losses, enhancing fertilizer use efficiency and crop yields (Neilsen *et al.*, 2004) [8]. The application of nutrients directly to the root zone through fertigation reduces the amount of applied fertilizer and allows adjustments based on the crop's actual needs throughout the growing season (Patel and Rajput, 2000) [10].

In the pursuit of sustainable agriculture, technological interventions like drip irrigation and fertigation are crucial. Efficient water utilization, precise nutrient application, and reduced environmental impact underscore the significance of these practices (Neilsen *et al*, 2000) [7]. The study aims to explore the impact of drip irrigation and fertigation on yield and economics of cauliflower that filling critical knowledge gaps and promoting resource-efficient cultivation practices. As agriculture grapples with the challenge of doing more with less, these innovative approaches promise to be integral to achieving sustainable and productive cauliflower cultivation.

Materials and Methods

The experiment was conducted at the Precision Farming Development Centre (PFDC), Water Technology Centre, IARI, New Delhi during months of rabi season of 2019-20. The farm is located in the West Delhi with geographical coordinates of latitude 28º 38' N and longitude 77º 10' E. Its average elevation is 230 m above mean sea level.

The experiment followed a randomized block design with four treatments and replicated five times, comprising of two types of fertilizer source under drip irrigation *viz*., conventional fertilizers (Nitrogen through Urea, P_2O_5 through SSP and K_2O through MOP) and fertilizers for fertigation (Nitrogen through Urea, P_2O_5 through Urea phosphate and K_2O through SOP). The experimental soil had a typical Yamuna alluvial profile with a sandy loam texture, consisting of 72% sand, 12% silt, and 16% clay. Initial soil physical and chemical parameters are depicted in Table 1. The soil had a pH of 7.32, electrical conductivity of 0.17 dS m^{-1}, organic carbon content of 1.6%, available N-106.12 kg ha^{-1}, P-24.32 kg ha^{-1} and K- 164.25 kg ha^{-1}. The irrigation water used in the experiment had an EC of 1.62 dS/m, RSC of 1.7 meq L^{-1} and pH of 7.15. Soil moisture content at field capacity and permanent wilting point was 24.3% and 7.3%, respectively and 1.46 cm/h hydraulic conductivity. The location of New Delhi lies in the "Trans-Gangetic plains" agroclimatic zone, characterized by a semi-arid and sub-tropical climate. The area experiences dry, hot summers and cold winters. During the two crop growth seasons, the region received rainfall of 13.6 mm and 79.2 mm, respectively.

Field was well ploughed with disc arrow followed by cultivator. Uniformly, FYM @ 5t ha^{-1} was applied at 15 days before red cabbage sown. Field was levelled and divided into 20 plots to assign treatment randomly. Drip pipes were installed before sowing of the crop. Experimental gross plot size, lateral spacing, emitter spacing and drip discharge rate were 5 m x 3 m, 0.45 m, 0.45 m and 2 L h^{-1}. One month old seedlings of cauliflower (Pusa Sharad) were transplanted at 60 cm × 45 cm spacing in second fortnight of September and harvested in first week of December.

The recommended fertilizer dosage consists of 76:46:83 Kg of nitrogen, phosphorus, and potassium (NPK) per hectare. Fertigation was implemented through a venturi system in 20 equal split applications, scheduled at 3–4-day intervals, commencing from September 21, 2018, throughout the experiment until November 25th. Water-soluble fertilizers, including Urea, Urea phosphate, and SOP, were utilized for fertigation. Following each fertigation session, the drip system underwent a thorough flushing for a duration of 5 minutes. Different fertilizer doses were applied by adjusting the supply through the manipulation of opening and closing knobs strategically positioned. The irrigation schedules were determined using CROPWAT 8.0 software, employing the Penman–Monteith approach developed by the Land and Water Division of FAO in 2009. The irrigation amount was calculated based on gross irrigation requirements, and pumping time per application, with the irrigation duration contingent on daily crop evapotranspiration (ETc.).

At the harvest stage, various yield parameters for cauliflower were documented, encompassing net curd weight, marketable curd weight, and overall yield. Net curd weight (g $plant^{-1}$), which includes the stalk at marketable maturity, was measured in grams. Marketable weight (g $plant^{-1}$) represented the total weight of the plants, encompassing the stalk, inner leaves, and curd, measured in grams. The yield of net curd weight for all plants within plots was converted to t/ha. The cost of cultivation encompassed expenses related to land preparation, seed procurement, sowing and transplanting, nursery raising, planting, intercultural operations, fertilizers, their application, plant protection measures, irrigation water, and harvesting. Gross returns were calculated by considering the prevailing average market price of the product during the experimental period. Net returns were determined by subtracting the total cost of cultivation from the gross returns. The benefit-cost ratio (BCR) for each treatment was computed by dividing the net return by the cost of cultivation, all expressed in rupees per hectare (₹ ha^{-1}).

The information obtained from the two-year investigation underwent analysis through a three-factor analysis of variance (ANOVA) test, employing a split-split plot design as recommended by Gomez and Gomez (1954). The critical difference (CD) for estimated treatment contrasts was determined using established statistical methods. The least significant difference (p=0.05) was calculated to indicate variations among the treatments.

Table 1: Soil physical and chemical properties

Sl. No.	Parameters	Values	Method followed	Reference
I	**Physical properties**			
1	Particle size distribution			
	a. Sand (%)	72	International pipette method	Piper, 1966
	b. Silt (%)	12		
	c. Clay (%)	15		
2	Bulk density	1.56	Core sampler method	Jackson, 1967
II	**Chemical properties**			
1	pH (1: 2.5)	7.32	Beckman's pH meter	Piper, 1966
2	EC (ds m^{-1})	0.17	Conductivity bridge	Piper, 1966
3	OC (%)	1.02	Wet oxidation method	Jackson, 1973
4	Available N (kg ha^{-1})	106.12	Alkaline permanganate method	Subbaih and Asija, 1956
5	Available P (kg ha^{-1})	24.32	Olsen's method	Jackson, 1973
6	Available K (kg ha^{-1})	164.25	Flame photometer	Jackson, 1973

Treatment details

Tr. No.	Treatments
T_1	Drip fertigation using 100% recommended dose of fertilizers as per prescribed schedule
T_2	Drip fertigation using 75% recommended dose of fertilizers as per prescribed schedule
T_3	Drip irrigation using 100% conventional fertilizer (Soil application)
T_4	Drip irrigation without application of fertilizers.

Results and Discussion

Cauliflower yield parameters: The productivity of a variety, as indicated by its yield, plays a crucial role in determining its commercial feasibility and acceptance. It stands out as a paramount trait in research initiatives. Yield represents the outcome of intricate interactions involving factors such as soil properties, climatic conditions, leaf area, and various metabolic and biochemical processes occurring throughout the crop's growth. Specifically, curd yield is impacted by the accumulation of dry matter in various plant parts, with attributes like curd weight, curd length, and curd width being the results of the interactions among the mentioned factors.

Fresh net curd weight and fresh marketable curd weight was significantly influenced by the fertigation treatments (Table 2.0). Significantly higher fresh net curd weight and marketable curd weight was recorded under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (656.2 g and 890.3 g) whereas, the lowest values were recorded under T_4: drip irrigation without fertilizers (428.4 g and 650.7 g) for fresh net curd weight and fresh marketable curd weight, respectively. The increase in cauliflower dry matter with application of nutrients through fertigation in every week, which accelerated photosynthesis and translocation of photosynthates in to storage organ, resulting in an increased length and width and weight of cauliflower (Guler *et al.*, 2008) [4]. Fresh and dry weight of curd was influenced by the fertigation levels and crop meets out its nutritional requirement in better proportion from application of nutrients through T_1 which resulting in luxurious crop growth and thereby enhancing the curd weight.

The curd yield data for cauliflower was impacted by the various drip fertigation treatments outlined in Table 2.0. The data indicated noteworthy differences in curd yield per hectare (t ha^{-1}). T_1, involving drip fertigation with 100% of the recommended dose of fertilizers as per the schedule, exhibited significantly higher curd yield for cauliflower (27.8 t ha^{-1}), whereas T_4, involving drip irrigation without fertilizers, recorded the lowest curd yield (20.5 t ha^{-1}) compared to other treatments. However, it was statistically equivalent to T_3, involving drip irrigation with 100% conventional fertilizer applied to the soil. The curd yield under T_1 surpassed the control by 135%. The increased curd weight and yield can be attributed to elevated fertigation levels. The superior yield parameters in T_1 may be linked to more effective water and nutrient utilization. Additionally, with the 100% recommended dose of fertigation treatments, nutrients were applied in 20 split doses, ensuring optimal nutrient concentrations at various growth stages, thereby contributing to higher curd weight and yield. These findings align with previous studies on cauliflower, such as Kadam *et al.*, (2006) [6], Singla *et al.*, (2007) [14], Guler *et al.*, (2008) [4], and Yanglem and Tumbare (2014) [16], which also highlighted the positive impact of higher fertigation levels on cauliflower yield.

Economic analysis: The benefit-cost ratio for various drip fertigation treatments is presented in Table 3.0. Upon examination of the data, it was observed that the highest gross income was achieved in T_1, involving drip fertigation with the 100% recommended dose of fertilizers as per the schedule, amounting to Rs 3,34,560 per hectare. Following closely was T_2, representing drip fertigation with 75% of the recommended dose, with a gross income of Rs 3,05,160 per hectare. Similarly, maximum net returns were observed in T_1 (Rs 2,48,866 per hectare), followed by T_2 (Rs 2,17,346 per hectare). The treatment with 100% of the recommended dose of fertilizer (T_1) exhibited the highest benefit-cost ratio (2.8), followed by T_2 with 75% of the recommended dose and T_3 involving drip irrigation with 100% conventional fertilizer. Conversely, the lowest benefit-cost ratio was recorded under T_4, where no fertilizer was applied. The relatively higher benefit-cost ratio under T_1 could be attributed to increased marketable yield and nutrient availability, as the cost of fertilizer application was minimal due to split doses in fertigation. Similar findings were reported in studies on radish, guava, and cotton by Fanish and Muthukrishnan (2011) [1], Ramniwas *et al.*, (2013) [13], and Raj *et al.*, (2015) [12], respectively.

Table 2: Effect of drip fertigation levels on fresh net curd weight, fresh marketable curd weight and yield of cauliflower.

Treatment	Fresh net curd weight (g)	Fresh marketable curd weight (g)	Curd yield per hectare (t ha^{-1})
T_1	656.2	890.3	27.88
T_2	572.2	786.3	25.43
T_3	583.5	803.5	24.45
T_4	428.4	650.7	20.52
Mean	560.1	782.7	24.57
S.Em	10.4	12.3	0.23
$CD_{0.05}$	32.4	37.8	0.70

Table 3 Economic analysis of cauliflower under different drip fertigation levels.

Treatment	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Net B:C ratio
T_1	85,694	3,34,560	2,48,866	2.80
T_2	87,814	3,05,160	2,17,346	2.47
T_3	85,764	2,93,400	2,07,636	2.42
T_4	79,224	2,46,240	1,60,476	2.02

*Sale Price of cauliflower curd -12 Rs kg^{-1} of curd

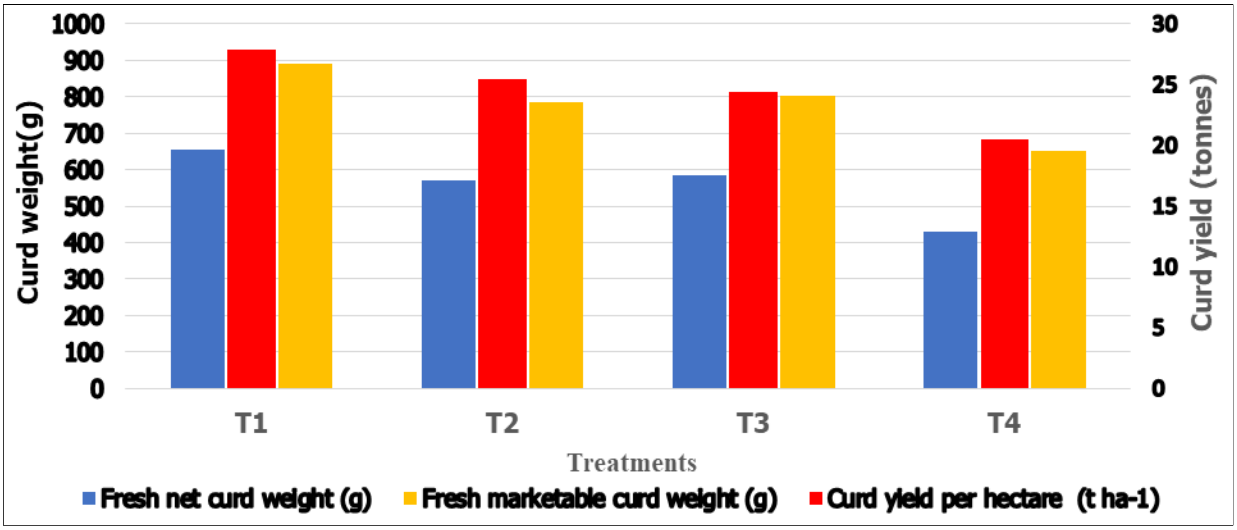

Fig 1: Effect of drip fertigation levels on fresh net curd weight, fresh marketable curd weight and yield of cauliflower

Conclusion

Based on the investigation, it can be inferred that various fertigation levels had diverse effects on cauliflower yield and economic evaluations. However, substantial differences were observed between fertigation using the 100% recommended dose and other treatments. The highest benefit-cost (B:C) ratio of 2.9 was achieved when applying 76:46:83 Kg N_2:P_2O_5: K_2O per hectare through fertigation. Consequently, the research suggests that employing the recommended fertilizer dose through drip irrigation in 20 intervals results in increased curd yield, making it a favorable practice for cultivating mid-maturity cauliflower varieties in the northern plains of India.

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