मिड-सीज़न फूलगोभी में ड्रिप फर्टिगेशन लेवल का मानकीकरण (*ब्रैसिका ओलेरासिया* वार। *बॉट्रीट्री* एल।)

Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea* var. *botrytis* L.)

Kishor N
Roll No. 21041

Water Technology Centre
ICAR-Indian Agricultural Research Institute
New Delhi 110012

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ICAR-Indian Agricultural Research Institute
(Indian Council of Agricultural Research) New Delhi – 110012, India

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Approved by Advisory Committee:

Chairman: Dr. Man Singh

Co-Chairman: Dr. Manoj Khanna

Members: Dr. Murtaza Hasan

Dr. Rajanna G A

Dr. Shrawan Singh

ICAR-Indian Agricultural Research Institute
(Indian Council of Agricultural Research) New Delhi – 110012, India

Dr. Man Singh
Professor & Project Director
WTC, IARI, New Delhi - 110012

CERTIFICATE

This is to certify that the thesis entitled **" STANDARDIZATION OF DRIP FERTIGATION LEVELS IN MID-SEASON CAULIFLOWERNITR (*Brassica oleraceae* var. *botrytis* L.)"** submitted to the Faculty of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfillment of **MASTER OF SCIENCE IN WATER SCIENCE AND TECHNOLOGY**, is a record of bona fide research work carried out by **Mr. KISHOR N, Roll No. 21041,** under my guidance and supervision, and that no part of this thesis has been submitted for any other degree or diploma. It is further certified that all the assistance and help availed during the course of investigation as well as source of information have been duly acknowledged by him.

Date: 24th June 2019

Place: New Delhi

(Man Singh)
Chairman,
Advisory Committee

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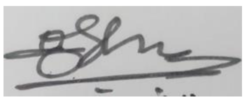

(Kishor N)

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ABBREVIATIONS

%	Percent
Ca	Calcium
CD	Critical difference
cm	Centimeter
Cu	Copper
cv	Cultivar
dS m^{-1}	Deci Siemens per meter
EC	Electrical conductivity
et al	Co-worker
Fe	Iron
g	Gram
g $plant^{-1}$	Gram per plant
HCl	Hydrochloric acid
$HClO_4$	Per chloric acid
Ha	Hectare (10,000 m^2)
i.e.	*That is*
K	Potassium
Kg ha^{-1}	kilogram per hectare
Kg	kilogram
M	Meter
Mg	Magnesium
mg kg^{-1}	Milligram per kilogram
ml	Milli liters
Mn	Manganese
N	Nitrogen
OC	Organic carbon
^{o}C	Degree Celsius
P	Phosphorus
pH	*Puissance de Hydrogen*
ppm	Parts per million
q ha^{-1}	Quintal per hectare
RBD	Randomized block design
S	Sulphur
$SnCl_2$	Stannous chloride
SO_4-S	Sulphate sulphur
Viz.	*Videlicet*
Var.	variety

CHAPTER – 1 INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most important vegetable crops widely grown in India and all over the world under temperate to tropical climatic conditions (Singh *et al*., 2009). It is the most important *Brassica* vegetable under cole crops group due to its delicious taste, flavour and nutritive value. The cole crops include cabbage, cauliflower, Brussel's sprouts, kale and collards, kohlrabi, and broccoli. Cauliflower ranks high among the vegetable crops due to its unique nutritional values and glucosinolates. It shares around 2.33% of total area under vegetable crops and contributes nearly 2.36% of total vegetable production in the world (FAOSTAT, 2014). India is the second largest producer of cauliflower and other *Brassicas* after China with the total production of 8.97 million tonnes with an area of 4.07 lakh hectares (NHB Database, 2017).

Cauliflower is originated in Eastern Mediterranean and introduced in India during 1822 (at Saharanpur). It has gone through genetic changes and evolved 'Indian type' which grows well under Indian tropical climate. Based on temperature requirement during curding, tropical cauliflower has been grouped into early (September –October; 20-27 °C for curding), mid-early (October to November; 16-20 °C for curding) and mid-late (December – January; 12-16 °C for curding). 'Pusa Sharad' is an improved variety of Indian cauliflower which can be grown from mid-November to mid-December. The growing period of mid maturity group cauliflower spans from September to November months which coincides with receding of monsoon. This period also affects the nutrient balance of the soil because of excess rains causing leaching and washing losses to the nutrients. Cauliflower is a shallow rooted and irrigation intensive crop. Its roots are confined to 45 to 60 cm soil depth. It requires uniform supply of moisture and nutrients throughout the growing season. It is sensitive to moisture stress at different growth stages and stress at any critical stage reduces its quality and productivity. Most of the area under cauliflower is rain fed which affects the productivity. The major constraints in cauliflower production include the traditional way of fertilizer application and lack of irrigation water. Drip irrigation is the most suitable method for uniform head size and high quality produce.

There is an imperative need to produce more from less arable land and water. The continuous improvement in productivity with optimum utilization of water, fertilizer and natural resources is essential for sustainability of any production system. Apart from the economic considerations, it is well established that the adverse effect of injudicious use of water and fertilizers can also have adverse implications on the environment. Hence, there is a need for technological interventions that will help in minimizing the use of precious resources (fertilizer and water) and maximizing crop production without any detrimental effects on the environment. Among the various techniques of water and nutrient application, the micro irrigation practices are very efficient and water conserving in nature. The drip or trickle irrigation is gaining more importance nowadays due to the many unique advantages it provides like conservation of soil moisture, optimum utilization of water resources, lesser wastage of nutrients, proper and sustained water and nutrient availability to the crop. It delivers water and nutrients directly to the root zone of the crop and water is applied in precise amount which synchronizes with the requirement of the crop.

Application of plant nutrients by dissolving them in irrigation water particularly with the drip system is termed as fertigation, offers a vast potential for more accurate and timely crop nutrition, preventing the leaching and volatilization losses of nutrients. The major advantages of fertigation are in saving of labour, appropriate timing of application of water and nutrients and their uniform distribution (Raina, 2002). Fertigation minimizes leaching and volatilization losses, and enhances fertilizer use efficiency with higher crop yields (Raina *et al.,* 2011). Interestingly fertilizer use efficiency can be increased from 80 to 90 per cent through liquid fertilizer as well as water soluble fertilizers (Paramasivam *et al*., 2001). Fertigation allows application of nutrients exactly and uniformly to the wetted root volume which remarkably increases the application efficiency of the fertilizer thus reducing the amount of applied fertilizer. On the other hand, fertigation allows adopting the amount and concentration of the applied nutrients in order to meet the actual nutrient requirement of the crop throughout the growing season. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand (Patel and Rajput, 2000). Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses (Neilsen *et al.*, 2004).

Emphasis on the fertilizer application rate, source, timing and nutrient balance is critical for achieving good productivity of the crops. Most of the work on fertigation has been carried out using conventional NPK fertilizers. The indiscriminate and unbalanced use of nutrients exhibits adverse effect on productivity. However, the information on use of water soluble fertilizers, which has recently been introduced in the country especially for fertigation, is scanty. Furthermore, nutrient status is expected to vary markedly under fertigation and soil fertilization. Hence, there is a need to study the availability of nutrient elements applied through drip irrigation system.

The work on drip irrigation and fertigation has been carried throughout the world (Neilsen *et al*, 2000) which mainly pertains to the flat lands having high productivity and assured irrigation. Such finding cannot be replicated to the vegetable crops raised on marginal lands, steep slopes /undulating topography/ polyhouse cultivation having variable agro –climatic conditions, competed with scare water availability and low crop productivity. The only viable remedy under such conditions is to harvest the rain water, store it and utilize the same through efficient micro- irrigation system such as drip/ sprinkler. In fact, it calls for total switch over from conventional methods to efficient technique of irrigation and fertigation.

A retrospective analysis of work done on the above mentioned problems showed very limited information on vegetable crops especially on cauliflower. However, the solubility of fertilizer and uptake of nutrients fertilizers under drip fertigation varies with the amount of irrigation water and intervals. Likely the nutrients and water distribution varies based on the rooting behaviour of cauliflower. However, no or limited information is available on suitable fertigation levels. Hence, the present study was proposed to determine the effect of drip irrigation, fertigation on nutrient availability, yield and quality of cauliflower with the following objectives:

1. To study the crop response and standardize fertigation levels in cauliflower.
2. To study the economics of cauliflower production under drip fertigation.

CHAPTER – 2 REVIEW OF LITERATURE

Efficient use of nutrients and water is becoming important everywhere and particularly in the areas where water is a scarce commodity. Fertigation is a method of fertilizer application in which fertilizer is incorporated within the irrigation water by drip system. In this system fertilizer solution is distributed evenly in irrigation. The availability of nutrients is very high thus, efficiency is more. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand (Patel and Rajput 2000; Narda and Chawla 2002). Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses (Deolankar, 2004). However, due to frequent application of water, optimum split applications of fertilizer improve quality and quantity of crop yield than conventional practice. In the present chapter, pertinent literature on the effect of drip fertigation on nutrient availability and growth characteristics of cauliflower has been reviewed under the following heads:

1. Effect of drip fertigation on plant growth, yield and quality of crop

Bucks *et al*. (1982) reported increased water use efficiency (90-95%), higher yield (40-100%), decreased tillage requirements, high quality products, higher fertilizer use efficiency (saving fertilizer up to 30%), lesser weed growth, less occurrence of pest and disease and reduced labour requirements etc. and also described that micro-irrigation system has potential to increase productivity per unit volume of water and also save up to 50% water in addition to other input costs.

Deolankar *et al*. (2004) studied use of fertilizer briquette for cabbage. The field experiment was conducted on sandy clay loam with organic carbon (0.43%), available N (154.88 kg ha^{-1}) available P (11.09 kg ha^{-1}) and available K (263.65 kg ha^{-1}). The treatments were allocated to factorial randomized block design with three replications. In non-briquette form treatment, the recommended basal dose of 80: 80: 80 kg ha^{-1} of NPK was supplied through urea, dia-ammonium phosphate (DAP) and muriate of potash (MOP) respectively just before transplanting. The study revealed that the highest yield of cabbage obtained per unit-applied nutrients was higher with drip irrigation and 60 percent NPK applied through briquette forms of fertilizers.

Kadam *et al*. (2006) conducted a trial on thirty-day-old seedlings of cauliflower cv. Golden 80 and applied fertigation treatment with 60, 80, 100, 120 and 140% recommended NPK rates at Rahuri, Maharashtra, India. Fertigation with 80% of the recommended NPK rates resulted in the highest average plant survival (98.03%), average plant height (95.9 cm), crop yield (554 q ha^{-1}), water use efficiency

(18.95 q ha-cm^{-1}), fertilizer use efficiency (230.9 kg ha^{-1}) and the lowest number of days required to harvest curds after initiation (13 days).

Rajput and Patel (2006) conducted experiment at IARI, New Delhi revealed that the yield of onion was not significantly affected in daily, alternate day and weekly fertigation, though there was a trend of lower yields with monthly fertigation. The highest yield was recorded in daily fertigation (28.74 t ha^{-1}) followed by alternate day fertigation (28.40 t ha^{-1}). Lowest yield was recorded in monthly fertigation frequency (21.40 t ha^{-1}). Application of 56.4 cm irrigation water and 3.4 kg ha^{-1} urea per fertigation (daily) resulted in highest yield of onion with less leaching of NO_3-N.

Singh *et al*. (2000) studied the effect of irrigation on yield of cauliflower. They reported highest yield of cauliflower to the tune of 120.7 q ha^{-1} and 105q ha^{-1} of early cauliflower were found under irrigation schedule based on IW/CPE=0.5 and 100% of recommended nitrogen dose, respectively. The crop response was positive to nitrogen application in its square root terms indicating favourable influence on crop yield at higher doses. Curd yield increased with increased rates of nitrogen. Water-use efficiency was also highest with IW/CPE = 0.5 and 100% rate of nitrogen.

Guler *et al*. (2008) worked on the effect of nitrogen (N) concentrations (0, 100, 150 and 200 mg N/liter) and their applications frequencies (once and twice per week) on yield and leaf nutrient content of drip –fertigated cucumber. The highest yield (75.2 t ha^{-1}) was obtained with the application of 200 mg N/litre twice a week. Irrespective of application frequency, the highest total yield was produced with 200 mg N/litre (71.2 t ha^{-1}). N application twice a week also resulted in higher early yield compared to once a week application. The other traits which affected by N concentration and the application frequency were fruit number and chlorophyll content of the leaf.

Kadam *et al*. (2008) indicated that when the quality of irrigation water was good (C3SI) and water soluble fertilizer of acidic in nature were used then the, higher yields (554 q ha^{-1}) were recorded due to fertigation along with saving of 20 per cent quantity of fertilizers as application of fertilizer at the rate of 80 per cent of RD gave yield as compared to conventional method of fertilizer application.

Rekha and Mahavishnan (2008) observed increased growth and yield with drip irrigation in several crops and the increase in yield ranged between 7–112% depending on the crops/varieties and method of irrigation. The water and fertilizer savings through drip fertigation were reported to be 40–70 and 30–50 per cent, respectively.

Abouel-Magd *et al. (*2009) reported that application of 100% NPK + chicken manure gave the highest significant increases in spear yield followed by soil addition with 100% NPK solely. Meanwhile, drip fertigation with 100% NPK + humic substances recorded the highest values followed by drip fertigation with 75% NPK + humic substances. Stalk number and head height was significantly higher in fertigation with 75% NPK + humic substances with respect to head diameter, where it was significantly higher in fertigation with 100% NPK + humic substances compared to the other treatments. Results also indicated that, the highest increase in macro and micro nutrients except for copper nutrient absorbed by shoots and spear produced from plants injected with 100% of NPK + humic substances with significant difference among them. On the other hand, lowest values of these nutrients were obtained from plants, received soil addition with 75% of NPK solely under drip irrigation system.

Gupta *et al.* (2010) reported significant improvement in yield, quality, water and fertilizer use efficiencies of capsicum under drip irrigation and fertigation. However, the combined effect of drip irrigation and fertigation was found superior to their individual effects. The treatment combination of 80% ET through drip and 80% recommended NPK through fertigation registered highest fruit yield (366.5 q ha^{-1}). The fertilizer use efficiency was found highest (NUE-4.89 q kg^{-1} N, PUE-6.53 q/kg P and KUE-9.79 q kg^{-1} K) under the treatment combination of 80% ET though drip + 60% recommended NPK through fertigation.

Savitha *et al.* (2010) reported that, fertigation with 75 per cent recommended dose of fertilizers (75, 112.5 and 56.25 kg of NPK ha^{-1}) registered higher bulb yield (10.30 and 12.70 t ha^{-1}) in onion var. Agri Found Dark Red. In small onion var. COO5 (Aggregatum onion), the fertigation with 75 per cent recommended dose of fertilizers (45, 45 and 22.5 kg of NPK ha^{-1}) registered higher bulb yield (8.34 and 11.05 t ha^{-1}) as compared to the soil application of fertilizer. The nutrient uptake also increased with application of 75 per cent recommended dose of fertilizer as fertigation.

Zhang *et al.* (2010) observed that both fruit yields of tomato and net economic returns responded quadratically to the fertilizer N rate, with a highest marketable yield of 127 Mg ha^{-1} averaged across the 3 yrs. The fertilizer N rates were 271 kg N ha^{-1} for the highest marketable yield and 265 kg N ha^{-1} for the optimum economic yield. These values are considerably greater than the current recommendation, due to the largely increased yield with drip fertigation. Fertilizer N should be applied at an increased rate for processing tomatoes through drip fertigation to maximize the economic returns.

Shashi Suman (2011) studied the effect of drip irrigation, fertigation and mulch on nutrient distribution and productivity of apple. The study revealed that drip fertigation significantly increased the growth parameters (annual shoot growth, tree height, EW canopy spread and canopy volume) over conventional soil fertilization methods. Different levels of fertigation had variable impacts on growth characteristics of apple and difference between fertigation with 100% and 80% of recommended dose were statistically at par.

Kumar *et al*. (2012) reported that application of fertilizer through drip system of irrigation (fertigation) increased the nutrient use efficiency as a result of better absorption and increase in the response of applied nutrients in cabbage crop. Increasing the irrigation and nitrogen levels increased the yield of cabbage significantly and highest yield (30.60 t ha^{-1}) was obtained with drip irrigation at 100 per cent PE and fertigation with 150 per cent of recommended dose of nitrogen (29.71 t ha^{-1}) as compared to furrow irrigation at 1.2 IW/CPE (22.55 t ha^{-1}). Water use efficiency was found to be higher under drip irrigation at 40 per cent PE (9.80 q ha-cm^{-1}) over furrow irrigation at 1.2 IW/CPE (8.08 q ha-cm^{-1}).

Patil *et al.* (2012) revealed that 2-day irrigation interval with 100 kg N ha^{-1} application in 17.5 × 30 cm crop geometry gave the highest yield (41.4 t ha^{-1}) with 6 per cent increase in yield as compared to rest of the treatments. The same treatment has resulted into maximum net seasonal income, benefit-cost ratio (BCR) and lowest payback period for both the years, respectively.

Vasu and Reddy (2013) observed that daily fertigation of N and K (100% recommended dose) resulted in highest cabbage yield (16.92 t ha^{-1}) and was associated with higher content of N (3.18%) and K (4.60%). The high est N (100.50 kg kg^{-1}) and K (131.37 kg kg^{-1}) fertilizer use efficiency was recorded in daily fertigation of 75%RDF of N and K but highest water productivity (7.92 kg m^{-3}) was found with daily fertigation with 100% RDF. Uptake of N (146.7 kg ha^{-1}) and K (189.4 kg ha^{-1}) head diameter (14.40 cm), TSS (4.66%) and ascorbic acid (118.4 mg 100 g^{-1}) content was highest at 125% RDF but B:C ratio of 3.03 was recorded in daily fertigation with 100% RDF.

Jayakumar *et al.* (2014) reported that yield attributes viz., number of sympodial branches per plant, number of fruiting points, bolls per plant, plant uptake and available soil N, P and K of Bt cotton were significantly increased by the drip fertigation treatments. Fertigation significantly increased the seed cotton yield and a progressive increase in seed yield was noticed with increasing levels of NPK fertilizer application. Application of nutrients through drip fertigation improved seed cotton yield by 43.0 per cent compared with conventional surface irrigation along with soil surface application of fertilizers.

Yanglem and Tumbare (2014) revealed that scheduling of irrigation at 1.2 ETc irrigation regimes recorded significantly maximum curd yield (37.58 t ha^{-1}) than 0.6, 0.8 and 1.0 ETc irrigation regimes. The higher fertigation level i.e., 100 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal dose registered maximum curd yield (38.94 q ha^{-1}). The highest photosynthetic rate, stomatal conductance and transpiration rate and minimum leaf temperature and stomatal resistance were observed due to 1.2 ETc irrigation regimes and 100 % RDF at all crop growth stages of cauliflower.

Jadhav (2015) reported from Rahuri that 100% RDF (100:50:50 kg N, P_2O_5 and K_2O per hectare) through drip irrigation recorded significantly higher plant height (78.71 cm), number of leaves (12.88), total dry matter production per plant (27.18 g), bulb diameter (6.66 cm) and total yield (37.58 t) followed by 80% RDF through drip irrigation (73.27 cm, 11.79, 24.72 g, 6.32 cm and 33.62 cm, respectively).

Jeevitha (2016) conducted experiment at Bengaluru reported that application of 80% recommended dose of fertilizers through fertigation with a spacing of 20 cm X 15 cm gave significantly higher plant height (55.76 cm), number of leaves (6.77), leaf width (1.50 cm) at 90 DAT and higher bulb diameter (6.47 cm) and bulb yield per hectare (36 tonnes).

2. Effect of drip fertigation on availability of nutrients, uptake and leaf nutrient content

Hara and Saha (2000) observed that total N uptake in tomato was remarkably enhanced with increased availability of soil moisture. Higher uptake of N was recorded when irrigation was applied at 25 per cent depletion of available soil moisture content.

Khuzwayo (2003) conducted the experiment in open field at Tsukuba international centre (TBIC) to find out the effect of nitrogen and fertilizer placement on the growth and yield of two cabbage cultivars (Shoshu and Misaki). The results showed that standard amount of nitrogen with broadcast of furrow in both cultivars perform much better than no nitrogen application. Therefore, it was concluded based on the result that cabbage to grow requires a certain amount of N throughout the entire growing period depending on the variety different requirement.

Silber *et al*. (2003) studied the combined effect of irrigation and fertilization frequency on growth, yield and uptake of water and nutritional elements by lettuce (*Lactuca sativa* L., cv. Iceberg). The lettuce was planted in pots and irrigated daily with a constant volume of nutrient solution at different frequencies. The results showed that high fertilizer frequency induced a significant increase in yield, mainly at low nutrient concentration level. Yield improvement was primarily related to enhancement of nutrient uptake, especially P.

Hebbar *et al*. (2004) reported that drip fertigation had significantly higher N, P and K uptake (142.1, 13.3, 94.3 kg ha^{-1}, respectively) by tomato over furrow method of irrigation. Also there was significantly higher FUE under drip irrigation (205.5 kg kg^{-1} NPK) over furrow irrigation (170 kg kg^{-1} NPK). This was due to better availability of moisture and nutrients throughout the growth stages under drip system leading to better uptake of nutrients.

Neilson *et al.* (2004) studied the fertilizer programs for cabbage using slow release nitrogen. The study was conducted at the Coastal Plain Experiment Station Tifton Vegetable Park in Tifton, Georgia. The study revealed that the treatments which included standard quick release fertilizer fared better than those with Nitamin (Slow release N fertilizer - 30:0:0) alone. When the 100 percent N rate was applied as Nitamin in application, the yields were better than any other treatment with Nitamin. Treatments with reduced level of N in the split Nitamin applications produced significantly lower yields than most of the other treatments. These also had significantly smaller heads and lower marketability.

Rajput and Patel (2006) reported that more NO_3-N leached through the soil profile in monthly fertigation. The highest yield of onion was recorded in daily fertigation (28.74 t ha^{-1}) followed by alternate day fertigation (28.4 t ha^{-1}). Application of 56.4 cm irrigation water and 3.4 kg ha^{-1} urea per fertigation (daily) resulted in highest yield of onion with less leaching of NO_3-N.

Koumanov *et al.* (2009) reported that fertigation maintained constant and sufficient concentrations of N, P, and K in the soil providing optimum mineral nutrition for the raspberry plants. Proper irrigation and fertigation management could successfully retain the fertilizers in the root zone, thus preventing losses and eventual pollution of soil and groundwater.

Shedeed *et al*. (2009) reported that even distribution of nutrients in fertigation treatments the improved fertilizer use efficiency and resulted in lesser leaching of NO_3-N and K to deeper soil layers. Fertigation of P at any rate also resulted in more available P compared to soil applied treatment. The NO_3-N in lower soil layer was marginally affected under 75% and 100% NPK fertigation rates while, NO_3-N was appreciably higher under furrow and drip irrigation treatments with soil applied fertilizers.

Ueta *et al.* (2009) reported that the yield of Chinese cabbage increased with drip fertigation, even when the N application rate was reduced by 25% from that used in the conventional method. The plant recovery rate increased by 30% and the rate of N leaching into subsoil was reduced in comparison with the levels in conventional cultivation.

Ramachandrappa *et al*. (2010) indicated significantly higher nitrogen, phosphorus and potash uptake in chilli leaf, stem and fruit in fertigation with MAP, MOP and KNO3 at 125 per cent. The residual content after the harvest of green chilli revealed that the higher NO_3 level was observed at 30 to 45 cm soil layer in soil application of nutrient with furrow irrigation (34.7, 38.6, and 40.2 kg/ha) which was significantly superior over fertigation treatments.

Rajaraman *et al*. (2010) observed the effect of fertigation on nutrient uptake of leaves in two coriander genotypes Co CR-4 and CS 11. Drip fertigation with water soluble fertilizer at 125 %, 100 %, 75% RDF along with recommended normal fertilizer was carried out. The effect of varieties and nutrient application methods (drip fertigation and soil application) were reflected on differential rate of N, P, and K uptake by the crop. The nutrient uptake was higher under increased drip fertigation dose compared to soil application of nutrients. Among the drip fertigation doses, the N, P and K uptake was higher with 125 per cent drip fertigation compared to other treatments.

Gururaj (2012) revealed that drip irrigation at 1.0 PE up to tillering and 1.5 PE tillering to maturity with soil application of 100 per cent RDF recorded more available nitrogen (342.0 kg ha^{-1}), phosphorous (39.93 kg ha^{-1}) and potassium (262.7 kg ha^{-1}) content of the soil than other levels of treatments in aerobic rice.

Sanju (2012) revealed that drip fertigation of water soluble fertilizer at 100 per cent recommended dose of fertilizer (25:75:37.5 kg NPK ha^{-1}) in groundnut recorded higher plant height (42 cm), number of branches per plant (8.00), leaf area (1411.1 cm^2 $plant^{-1}$) and total dry matter (29.48 g $plant^{-1}$) at maturity than the conventional method of fertilizer application.

Jata *et al.* (2013) observed that for minimizing the cost of irrigation and fertilizers, adoption of irrigation and fertigation through drip is essential which will maximize the nutrient uptake, while using minimum amount of water and fertilizer. Fertigation gives advantages such as higher water and fertilizer use efficiency, minimum losses of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost.

Fanish and Muthukrishnan (2013) reported that among the different treatments, drip fertigation with 100% RDF in which 50% P and K were WSF increased the maize grain yield to the tune of 15.5% as compared to drip fertigation of 100% RDF with normal fertilizer. The increase in yield under 100% RDF with P and K as WSF might be due to the fact that fertigation with more readily available form obviously resulted in higher availability of all the three (NPK) major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink.

Kumar and Sahu (2013) reported that total uptake of nitrogen (287.93 kg ha^{-1}), phosphorus (25.30 kg ha^{-1}) and potassium (297.11 kg ha^{-1}) were maximum in drip irrigation at 100 per cent PE in cabbage. Similarly, maximum uptake of nitrogen (296.22 kg ha^{-1}), phosphorus (26.90 kg ha^{-1}) and potassium (309.74 kg ha^{-1}) were observed at fertigation with 150 per cent of recommended dose of nitrogen. Water use efficiency (WUE) was found to be higher under drip irrigation at 40 per cent PE (9.80 q ha^{-1} cm^{-1}) over furrow irrigation at 1.2 IW/CPE (8.08 q ha^{-1} cm^{-1}).

Rajaraman and Pugalendhi (2013) revealed that drip fertigation in bhendi at 125% recommended dose of fertilizers (250:125:125 kg NPK/ha) as water soluble fertilizer combined with Azophosmet (0.5% at 750 ml/ha) and humic acid (0.4% at 2.5 litre/ha) under wider spacing registered the highest leaf nutrient status like nitrogen (2.31%), phosphorus (0.53%), potassium (1.33%), calcium (0.59%), magnesium (1.46%), zinc (45.55 ppm), manganese (102.81 ppm) and boron content (16.70

ppm), whereas, the leaf copper content (22.31 ppm) was the highest under 100% recommended dose of fertilizers as water soluble fertilizer combination with Azophosmet and humic acid under wider spacing.

Fontes *et al*. (2014) reported that highest phosphorus (P), manganese (Mn), and iron (Fe) leaf contents were obtained from plants fertilized with single superphosphate at 79: 0: 0 g plant^{-1}, respectively. The marketable tomato fruit yield, measured up to 123 days after transplanting, increased with the increasing single superphosphate up to 54 g plant^{-1}, resulting in a yield of 6.16 kg plant^{-1}, corresponding to 10.3 kg m^{-2}. A settled aqueous solution of single superphosphate (54 g 210 mL^{-1} of water) can be applied weekly to tomato plant through a low pressure drip irrigation system during the plant cycle.

Kamble and Deshpande (2014) reported that application of 25% recommended dose of N through PBSW (primary treated biomethanated spentwash) + remaining N and P through mineral fertilizers increased the total Fe, Zn, Mn and Cu uptake by soybean and wheat, soybean-grain equivalent yield of wheat and benefit: cost ratio compared to 100 and 50% RD-N through PBSW treatments and improved the status DTPA-Fe, Zn, Mn, Cu, Ni, Cd and Pb as compared to RD-NPK at all 3 soil depths. However, heavy metal status values were below the permissible limits. Fertigation of 25% N-PBSW along with mineral fertilizers not only helps in improvement of the micronutrient status of soil but also prevent any adverse effect on soil health.

Ugade *et al*. (2014) observed that treatment F_1 (100%) RDF through WSF recorded significantly superior yield (36.74 t ha^{-1}) over fertilizer level F_2 i.e. 80% RDF through WSF (32.31 t ha^{-1}) in brinjal. The total nutrient uptake of nitrogen (144.4 kg ha^{-1}), phosphorus (44.13 kg ha^{-1}) and potassium (203.6 kg ha^{-1}) was noticed significantly higher under the fertigation level F_1 i.e. 100% RDF through WSF. The maximum fertilizer use efficiency of NPK was 71.81, 62.52, 153.7 per cent, respectively under the treatment F_2 i.e. 80% RDF through WSF.

Patil and Das (2015) revealed that the effect of drip irrigation and fertilizer management treatment were significant in capsicum in respect of per cent nitrogen content both in plant (2.18%) and fruits (1.19%). Similarly, highest uptake of P_2O_5 by plants (7.37 kg ha^{-1}) and by fruits (3.64 kg ha^{-1}) K_2O by plant (47.05 kg ha^{-1}) and by fruits (26.07 kg ha^{-1}) recorded in at 100% EPR alone with the application of 75% RD of N and K through drip. The nutrient status determined in terms of available N, P_2O_5, and in K_2O kg ha^{-1} was significantly influenced by different drip irrigation and fertilizer management significantly highest fruit yield (87.20 q ha^{-1}) was recorded in drip irrigation at 100 EPR along application of 75 % RD of N through drip irrigation over other treatments.

Saroch *et al.* (2015) reported from Palampur that irrigation and fertigation with micro-sprinkler led to less use of water i.e., 66.23%, 59.9% and 60.89% and significantly higher green pod yield of garden peas i.e., 10.75%, 30.05% and 10.02% during first, second and third years, respectively. Consequently, water use efficiency was significantly increased (3.67, 3.59 and 3.12 times, respectively) as compared to recommended practices.

3. Effect of drip fertigation on economics of cauliflower

Kavitha *et al. (*2007) revealed that the application of 100 per cent water soluble fertilizer under shade improved the growth parameters of tomato namely plant height, primary braches per plant, leaf area index and dry matter production at different stages of growth. The yield parameters like number of fruits per plant and fruit weight were highest with 100 per cent water soluble fertilizer under shade. The highest yields of 99.8, 109.5 and 106.7 t ha^{-1} during seasons I, II and III respectively was observed in the treatment with 100 per cent water soluble fertilizer under shade condition. The fruit quality parameters viz., fruit firmness, ascorbic acid, lycopene and carotene were improved with the application of 100 per cent water soluble fertilizer under shade. The economics of shade and fertigation showed that the treatment with 100 per cent straight fertilizers under shade registered the highest benefit: cost ratio of 2.90, 3.13 and 3.18 during seasons I, II and III respectively.

Fanish and Muthukrishnan (2011) recorded that drip fertigation at 100 per cent RDF with 50 per cent P and K as water soluble fertilizer in maize + radish intercropping system recorded a higher gross income of Rs. 83438 ha^{-1}, whereas, higher net return and benefit cost ratio of Rs. 56858 and 3.24, respectively, were recorded by drip fertigation at 150 per cent RDF with radish as the intercrop.

Ramniwas *et al*. (2013) reported that 57% irrigation of IW/CPE through drip resulted in maximum guava yield with quality fruits, leaf nutrient status and fertilizer use efficiency with highest net return (Rs. 2, 12,372.17) in ‘Shweta’ guava (*Psidium guajava* L.). Use of 45, 20, 20 g NPK $plant^{-1}$ $year^{-1}$ produced fruit yield (29.81 t ha^{-1}), quality of fruits with maximum net return (Rs. 2, 12,550.62). However, F_1 (30, 10, 10 g NPK $plant^{-1}year^{-1}$) exhibited highest fertilizer use efficiency (101.97 kg ha^{-1}). Interaction effect of irrigation and fertigation levels showed that 75% irrigation of irrigation water/ cumulative pan evaporation + 75 % water soluble fertilizer produced maximum fruit yield (32.79 t ha^{-1}) with quality fruits and highest net returns (Rs. 2,44,073.07).

Raj *et al*. (2015) observed higher N, P and K uptake (160.99, 28.57 and 134.87 kg ha^{-1}, respectively) in cotton under 100 per cent recommended dose of fertilizer with fertigation in 5 splits. The higher nutrient uptake in fertigation treatments was attributed to higher fertilizer use efficiency and nutrient availability in the soil as compared to recommended dose of fertilizer through soil application. Among different treatments, application of 100 per cent recommended dose of fertilizer with fertigation in 5 splits recorded higher net returns (79231 Rs. ha^{-1}) and B:C ratio (3.41). It is advisable to adopt 5 splits application of all the major nutrients under sub surface fertigation to achieve higher cotton productivity and increasing B: C ratio, besides higher cost of cultivation.

CHAPTER – 3 MATERIALS AND METHODS

The present investigation entitled **"Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea* var. *botrytis* L.)"** was carried out in the experimental Farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi during the rabi season of 2018-19. The details of materials used and methodologies employed are presented in this chapter:

1. GENERAL DESCRIPTION OF THE STUDY AREA

Experimental site

The experimental site is situated at the experimental farm of Water Technology Centre, Indian Agricultural Research Institute (IARI). IARI is situated in West Delhi between the latitudes of 23° 38’ 22" N and 33° 39’ 05” N and longitudes of 77°9’ 45“E and 77° 10’ 24” E at an average elevation of 228.61 in above the MSL. The research fields, which form a fundamental part of the IARI campus, cover an area of about 340 ha, of which about 300 ha is irrigated by an interlinked chain of tube-wells and water storage tanks.

Climatic conditions

Climate of Delhi is semi-arid, subtropical with hot dry summer and cool winter and it comes in the Agro-eco region-IV. The mean annual temperature is 25.5° C. May and June are the hottest months with 30 years’ normal maximum temperature of 39° C and which varies from 43.9 to 45.0° C. The period from December to February is the winter season. The mean temperature of 14° C in the month of January is considered to be coldest. However, the minimum temperature dips below 1° C. 75 % of the rainfall is received during monsoon season (June to September) from the mean annual rainfall of 710 mm. Some winter showers are also received during December month. Through western disturbances some frost also occurs occasionally during month of December-January. The average relative humidity (RH) in different months varies from 34.1 to 97.9 % and mean daily evaporation ranges between 3 to 9 mm/day. Average wind speed varies from 0.45 to 3.96 m s^{-1}.

Soil

Soils of IARI represent the Yamuna basin with a distinctive alluvium profile. The entire farm is covered under several soil series. The soil type ranges from sandy loam to clay loam. The texture up to depth of about 150 cm appears almost homogeneous. As per USDA textural classification, major portion of the area belongs to sandy loam class. There are only minor pockets representing clay, sandy clay and sandy clay loam texture classes. Porosity is about 40% and soil belongs to good class as far as its permeability is concerned.

The information on chemical characteristics and available nutrient status of the experimental soil, along with the procedures followed for their estimation and the obtained values are presented in Table 3.1.

Table 3.1. Physical and chemical characteristics of soil in the experimental site

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 (%)	16		
2	Bulk density	1.56	Core sampler method	Jackson, 1973
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	Subbiah 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
Leaf analysis				
Sl. No.	**Parameters**	**Method followed**		**Reference**
1.	N	Micro-kjeldhal method		Jackson, 1973
2.	P	Vando-molybdate phosphoric yellow color method		Jackson, 1973
3.	K	Flame photometer method		Jackson, 1973

2. LAYOUT OF FIELD TRIALS

Execution of field trials

Field trials were executed during the year 2018-2019 on cauliflower cv. ‘Pusa Sharad’. Pusa Sharad is a mid-early variety released by IARI in 2004 for NCR region. Its foliage is bluish-green, leaf with narrow apex and prominent midrib. It is having semi-dwarf shaped white and very compact curd with an average curd weight and yield of 900 g and 24 t ha^{-1}, respectively.

Nursery raising

Cauliflower seeds of Pusa Sharad variety were sown on 13-08-2018 in well prepared raised nursery beds. The soil of nursery was reduced to finest possible tilth before sowing and it was not fertilized heavily. The nursery beds were drenched with bavistin to control fungal diseases. For mid-early crop about 350-400 g seeds were sufficient. The surface of the bed was smoothened and seed was sown thinly in rows and covered with dried grass to conserve moisture and to hasten the germination. The seeds were germinated on 3-4 days and the beds were watered twice in the morning and evening by rose can. Before uprooting, the beds were thoroughly soaked with water to facilitate easy removal of seedlings without much injury. One month seedlings were transplanted in early morning hours.

Drip installation

An online drip fertigation system was designed and laid on the experimental plot for cauliflower crop. The control head of the system consisted of sand filter, screen filter, flow control valve, pressure gauges etc. The system was connected to fertigation pump for the application of fertilizers. A PVC sub main line (50 mm outer diameter, 6.0 kg cm^{-2} working pressure class was laid for the experimental area. Lateral lines of LDPE (16 mm diameter) were taken out from the sub main line for the irrigation of cauliflower crop. The lateral lines were spaced at 60 cm interval. The drip lateral lines with rated emitter discharge of 4 l h^{-1} were selected for the experiment. Drip system comprised eleven emitters in each row, placed at an angle of 180^{o} to each other at a distance of 45 cm. Each lateral line was provided with flow control valve at the start of the line to achieve specific irrigation and fertigation operation for each treatment.

Field preparation

Before the execution of experiment, Dhaincha, a green manure crop was incorporated into soil and allowed 3-4 days for decomposition. Field was well ploughed by tractor drawn disc furrow followed by cultivator 3 days prior to actual date of transplanting of seedlings. Weeds, stones, pebbles, etc. were removed from the field. Twenty plots of dimension 5 m x 3 m were made and drip lines were installed.

Transplanting of seedlings

One month old seedlings were transplanted on 21-09-2018 at a spacing of 60 cm x 45 cm. Each plot had five rows accommodating 55 plants and total 1111 seedlings were transplanted in 20 plots.

Gap filling

The gap filling was done after one week of transplanting to ensure uniform plant population.

Irrigation management

Irrigation was scheduled based on study of Hasan *et al.* (2010). Total of 20 numbers of irrigations were provided with varying time based on evaporation and crop stages. In initial stages irrigation interval is less due to more evaporation rate and in later stages irrigation interval was less due to low temperature. Irrigation schedule was followed as once in every two days vegetative stage and once in 3 days in curd maturation stage. Time of irrigation was calculated based on flow rate per emitter (4 lph), number of emitters and area.

Table 3.2 Irrigation schedule for the field experiment

No. of irrigations	Date	Duration (min)
1.	21-Sept	26
2.	24- Sept	26
3.	27- Sept	26
4.	31- Sept	28
5.	3-Oct	28
6.	6- Oct	28
7.	9- Oct	28
8.	12- Oct	29
9.	16- Oct	29
10.	20- Oct	29
11.	25- Oct	29
12.	30- Oct	29
13.	4-Nov	29
14.	8- Nov	28

15.	10- Nov	28
16.	13- Nov	28
17.	16- Nov	28
18.	19- Nov	26
19.	22- Nov	26
20.	25- Nov	26

Weed management

To keep the crop free of weeds, two manual weeding at 20 DAT and 45 DAT were carried out for the effective control of the weeds.

Insect pest and disease control

During the nursery raising Bavistin (2 kg ha^{-1}) was drenched to control damping off. In the field Confidor (1 ml lit^{-1}) was sprayed twice to control head borer and diamond black moth.

Method of fertigation

Fertigation was done through venturi in 20 equal split applications at 3-4days intervals, starting w.e.f. 21st September 2018 of experimental year and continued till 25^{th} of November. The water soluble fertilizer (Urea, Urea phosphate and SOP) was used for fertigation. The quantity of Urea, Urea phosphate and SOP was computed in Table 3.3. After each fertigation, drip system was thoroughly flushed for 5 minutes. Different doses of fertilizers were applied by regulating the supply with the help of closing and opening knobs put at appropriate places.

Table 3.3: Fertigation schedule adopted during crop season

Days after planting	Water soluble fertilizers (kg ha^{-1})		
	Urea (N)	Phosphorous (P)	Potassium (K)
1-30 (6 fertigation)	29.4	38.7	35.8
31-60 (8 fertigation)	36.0	47.3	43.9
61-90 (6 fertigation)	43.2	60.5	63.1

Note: 1. Recomended fertilizerdose 76:46:83 kg N_2: P_2O_5: K_2O per hectare.

2. Fertilizers for fertigation are Urea, Urea phosphate and SOP.

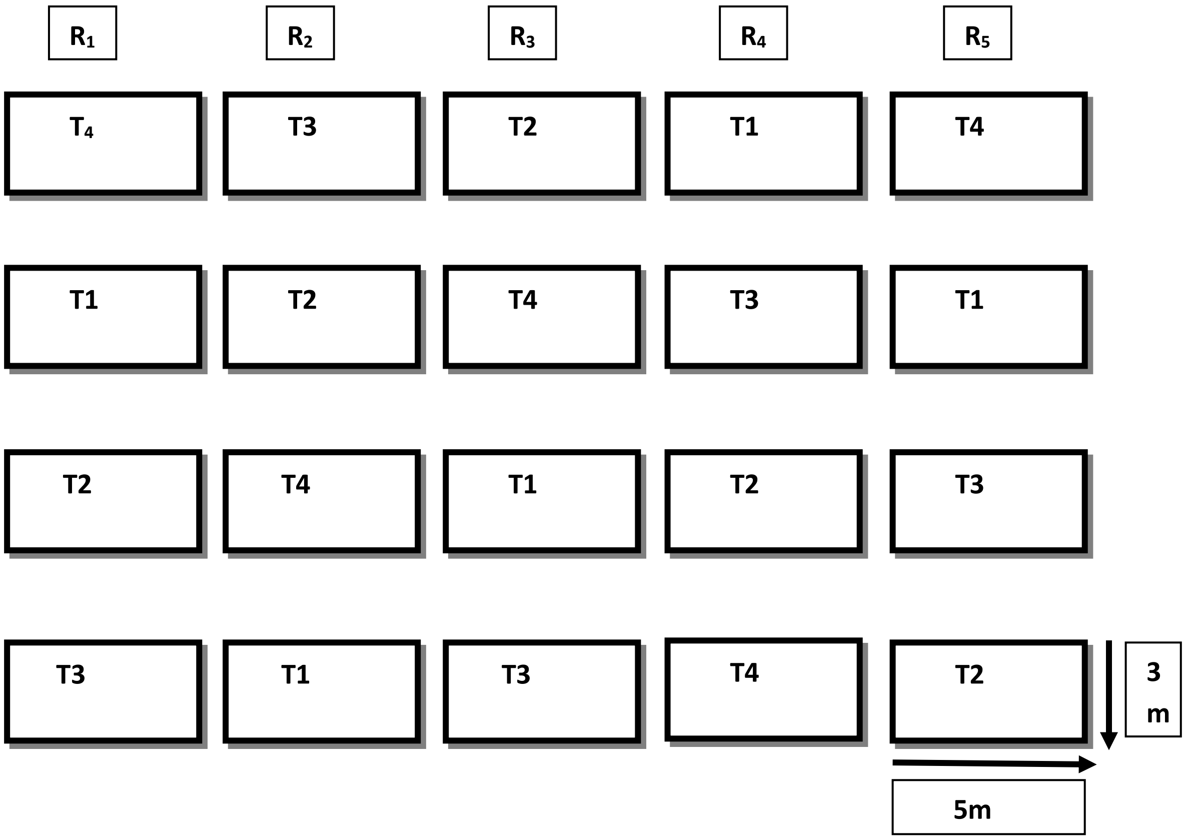

Fig.3.1 Plan of layout of experiment

Table 3.4: Treatment details of experiment

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

Fig.3.2 One-month old nursery seedlings

Fig. 3.3 Installation, design and spacing of drip lines

Experiment details

Crop	: Cauliflower (transplanted)
Variety	: Pusa Sharad
Situation	: Irrigated
Design of experiment	: RBD
Replications	: 5
Treatment	: 4
Spacing	: 60 cm × 45 cm
Plot size	: 5 m × 3 m
Fertilizer dose	: 76 : 46 : 83 kg N_2 : P_2O_5 : K_2O ha^{-1}.
Fertilizer management	: Applied as per fertigation schedule
Source of fertilizers	:

1) Conventional fertilizers- N through Urea, P_2O_5 through SSP and K_2O through MOP.

2) Fertilizers for fertigation – UN through Urea, P_2O_5 through Urea phosphate and K_2O through SOP.

3. PLANT CHARACTERISTICS

Five plants were randomly selected and tagged in each treatment to study the plant growth and curd characteristics as given below:

Plant height

The plant heights of five randomly selected plants were recorded. The plant height was measured from the ground level to the growing tip at 45 days after transplanting (DAT) and at harvest. The average height was calculated and expressed in centimetres.

Number of leaves per plant

The number of green leaves of five randomly selected plants was counted at 45 days after transplanting (DAT) and at harvest and average number of leaves per plant was worked out.

Leaf width

Leaf width (cm) was measured from middle of fully matured leaf at 45 days after transplanting (DAT) and at harvest was recorded by using scale.

Dry matter production and its distribution

The dry matter content in different parts i.e., leaves and curds of randomly selected plants were recorded at 45 days after transplanting (DAT) and at harvest stages by keeping the samples in hot air oven at a temperature of 70 °C for 48 hours and then average of five samples were calculated. Finally, the total dry matter content of plants was worked out and expressed in grams per plant.

ROOT PARAMETERS

Root weight

The root weight of five randomly selected plants was recorded at 45 days after transplanting (DAT) and at harvest and average root weight of plant was worked out. The root weight was expressed in grams.

Root length

The root lengths of five randomly selected plants were recorded. The root length was measured from the collar of stem to tip of main root at 45days after transplanting (DAT) and at harvest. The root length was calculated and expressed in centimetres.

4.SOIL AND LEAF ANALYSIS

Soil analysis

Initial soil samples were collected before planting from different depths and available nitrogen (N), phosphorus (P) and potassium (K) were determined by using standard laboratory methods. The available N was estimated by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) and available P content in soil was estimated by Olsen's method (Olsen et al., 1954). Available K was determined using neutral normal ammonium acetate extraction method and flame photometry as described by Jackson (1973) and expressed in kg/ha. A balance sheet of N, P and K used of the crop was prepared by comparing the net change in nutrient status of soil after harvest of the crop. Available N, P and K in 0-30 depths are presented in Table 3.1.

Leaf analysis

Collection and preparation of leaf foliage samples

Composite leaf samples were collected from the most recently fully matured leaves at curding stage of crop. The leaf samples were washed with tap water and then with 0.1N HCl and finally with double distilled water. The samples were spread on filter paper for air drying and were subsequently put in paper bags, which were kept in hot air oven at 60 ± 5°C for 48 hours for drying. The dried samples were crushed, ground and stored in butter paper bags for the estimation of N, P, K contents.

Digestion of leaf samples

Well ground samples of known weight of leaf were digested in diacid mixture prepared by mixing concentrated HNO_3 and $HClO_4$ in the ratio of 4:1 observing all relevant precautions as laid down by Piper (1966) for estimating P, K contents. Separate digestion was carried out for nitrogen (N) estimation using concentrated H_2SO_4 and digestion mixture (Potassium sulphate 400 parts, copper sulphate 20 parts, mercuric oxide 3 parts and selenium powder 1 part) as suggested by Jackson (1973). Nutrients were estimated following the methods given in Table 3.1.

5. YIELD PARAMETERS (AT HARVEST)

Curd width

The equatorial diameter (ED) at maximum thickness of the curd across polar length of five curds was measured with the help of scale and mean of 5 curds equatorial diameter (ED) was calculated.

Curd length

The curd length was measured from tip of curd to bottom of the curd at harvest. The average length was calculated and expressed in centimetres.

Net curd weight per plant

Curd weight (g $plant^{-1}$) including the stalk at marketable maturity was recorded in grams.

Marketable weight of curd per plant

Marketable weight (g $plant^{-1}$) is the total weight of the plants including the stalk, inner leaves and curd was recorded in grams.

Yield of cauliflower

Yield of net curd weight of all the plants per plots was converted to t/ha.

BENEFIT COST (B:C) RATIO

The benefit cost ratio was calculated by considering the cost of variable as well as fixed inputs and prevailing market rates, the expenditure incurred on various inputs and operations.

Simultaneously, gross returns were worked out for each treatment based on quality and market prices of the produce. The net returns were worked out by deducting the cost incurred from the gross returns of the particular treatment. Cost of cultivation has been detailed in table 4.13.

STATISTICAL ANALYSIS

The data generated from present investigation were subjected to statistically analysis using the statistical package OPSTAT. Critical difference (CD) at 5 % level was used for testing the significant difference among the treatment means.

Fig 3.4 Cauliflower crop at maturity stage

Fig 3.6 Data recording on plant growth parameters

Fig 3.5 Discussion with Dr. Man Singh, Professor and PD

Fig 3.7 NPK analysis in agronomy lab

CHAPTER – 4 RESULTS

The results emanating from the present investigation on "**Standardization of drip fertigation levels in mid-season cauliflower (*Brassica oleracea* var. *botrytis* L.)**" have been presented under the following headings with suitable tables and figures:

4.1 Effect of drip fertigation on plant growth attributes of cauliflower

The data depicting the effect of drip fertigation on plant growth (plant height, number of leaves, leaf length and width, fresh plant weight, dry plant weight, root length and root weight) are presented in Tables 4.1-4.14.

4.1.1 Plant height

The height of the plant was measured at 45 days after transplanting and at harvest. The plant height was significantly influenced by the various fertigation levels. The data on plant height at various fertigation levels are presented in Table 4.1.

The data revealed that different drip fertigation levels had significant effect on plant height at both 45 days after transplanting and at harvest. Significantly higher plant height was obtained under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (53.6 cm & 73.5 cm) while the lowest was observed under $T_{4:\text{ drip}}$ irrigation without fertilizers (44.5 cm & 64.6 cm) at 45 days after transplanting and at harvest respectively over other treatments.

Table 4.1: Effect of drip fertigation on plant height of cauliflower at 45 DAT and at harvest

Treatment	Plant height at 45 DAT (cm)	Plant height at harvest (cm)
T_1	53.6	73.5
T_2	46.8	67.4
T_3	48.2	68.6
T_4	44.5	64.6
Mean	48.3	68.5
SEm	0.4	0.7
$CD_{0.05}$	1.3	2.3

4.1.2 Number of leaves

The number of green leaves was counted at 45 days after transplanting and at harvest. The number of leaves was significantly influenced by the various drip fertigation levels at both stages. The data on number of functional leaves at various drip fertigation levels are presented in Table 4.2.

A glance of data in Table 4.2 showed that drip fertigation had a significant effect on the number of leaves of cauliflower at both 45 days after transplanting and at harvest. Likely, T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (12.3 and 19.4) at 45 DAP and at harvest, respectively as compared to other drip fertigation levels. Whereas, $T_{4:}$ drip irrigation without fertilizers produced significantly lower number of leaves (7.3 & 15.5) at respective crop growth stages.

Table 4.2: Effect of fertigation on number of leaves at 45 DAT and at harvest

Treatment	Number of leaves per plant at 45 DAT	Number of leaves per plant at harvest
T_1	12.3	19.4
T_2	9.5	17.3
T_3	10.5	18.4
T_4	7.3	15.5
Mean	9.9	17.6
SEm	0.4	0.7
$CD_{0.05}$	1.2	2.6

4.1.3 Leaf length and leaf width of cauliflower

Application of different fertigation treatments exerted a significant influence on the leaf length and leaf width of cauliflower at 45 days after transplanting and at harvest (Table 4.3). At 45 days after transplanting and at harvest, significantly higher leaf length was obtained under T1: drip fertigation with 100% recommended dose of fertilizers as per schedule (41.6 cm and 52.4 cm) respectively, while significant and lowest leaf length was observed in T_4: drip irrigation without fertilizers (34.2 cm & 45.2 cm) respectively as compared to other drip fertigation. Similar results were noted for leaf width at 45 DAP and at harvest. Significantly higher leaf width (15.3 cm and 22.4 cm) was noticed in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule while lowest leaf length was observed in T_4: drip irrigation without fertilizers (11.3 cm and 16.3 cm) at 45 days after transplanting and at harvest, respectively over other treatments.

Table 4.3: Effect of fertigation on leaf width and leaf length at 45 DAT and at harvest

Treatment	Leaf length at 45 DAT (cm)	Leaf length at harvest (cm)	Leaf width at 45 DAT (cm)	Leaf width at harvest (cm)
T_1	41.6	52.4	15.3	22.4
T_2	37.4	48.4	13.4	18.5
T_3	37.6	49.6	13.5	19.5
T_4	34.2	45.2	11.3	16.3
Mean	37.7	48.9	13.4	19.2
SEm	0.4	0.2	0.1	0.5
$CD_{0.05}$	1.2	0.9	0.8	1.6

4.1.4 Fresh and dry weight of cauliflower at 45 DAT and at harvest

It is evident from the data presented in Table 4.4 that different fertigation levels had significant effect on fresh plant weight and dry plant weight at 45 days after transplanting. The treatments showed significant difference for fresh plant weight and dry plant weight and the highest values were recorded with T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (323.5 g and 18.3 g) respectively. However significantly lower fresh and dry weight of the plant was recorded in T_4: drip irrigation without fertilizers (247.8 g and 15.48 g), respectively over other drip fertigation levels.

Table 4.4: Effect of fertigation on fresh and dry plant weight at 45 DAT and at harvest

Treatment	Fresh plant weight at 45 DAT (g)	Dry plant weight at 45 DAT (g)	Fresh plant weight at harvest (g)	Dry plant weight at harvest (g)
T_1	323.5	18.3	1334.7	92.2
T_2	288.8	16.2	1208.7	80.2
T_3	296.7	16.4	1224.9	81.7
T_4	247.8	15.4	992.2	59.7
Mean	289.2	16.6	1190.1	78.5
SEm	5.4	0.5	12.4	1.1
$CD_{0.05}$	16.8	1.7	38.2	3.3

Similar results were seen in case of fresh plant weight and dry plant weight. Significantly highest fresh plant weight and dry plant weight was recorded in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (1334.7 g and 92.2 g) while significantly lower fresh and dry plant weight of the cauliflower was recorded in T_4: drip irrigation without fertilizers (992.2 g and 59.7 g), respectively.

4.1.5 Root length of cauliflower

A perusal of data presented in Table 4.5 revealed that different fertigation treatments had significant effect on root length of cauliflower at 45 DAP and at harvest. Significantly higher root length was recorded with T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (15.5 cm and 21.5 cm) as compared to other drip fertigation levels at 45 days after transplanting and at harvest, respectively. While significantly lower root length was observed with T_4: drip irrigation without fertilizers (11.3 cm and 18.2 cm) at 45 days after transplanting and at harvest, respectively.

Table 4.5: Effect of drip fertigation levels on root length cauliflower at 45 DAT and at harvest

Treatment	Root length at 45 DAT (cm)	Root length at harvest (cm)
T_1	15.5	21.5
T_2	13.5	17.4
T_3	14.3	17.4
T_4	11.3	16.5
Mean	13.6	18.2
SEm	0.3	0.3
$CD_{0.05}$	0.9	1.1

4.1.5 Root weight of cauliflower

Data presented in Table 4.6 revealed that different fertigation treatments had significant effect on root weight of cauliflower at 45 DAT and at harvest.T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule recorded significantly higher root weight (43.4 g and 64.5 g) respectively, While lower root weight was recorded under T_4: drip irrigation without fertilizers (35.4 g and 48.4 g) at 45 days after transplanting and at harvest, respectively over other drip fertigation levels.

4.2 Effect of drip fertigation levels on curd and yield attributes of cauliflower

4.2.1 Curd width and curd length

The data pertaining to curd parameters as influenced by fertigation treatments enumerated in Table 4.7. The data reveals that significant differences were observed pertaining to parameters such as curd width and curd length.

Significantly higher curd width was obtained under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (16.4 cm) while the lowest was observed under T_4: drip irrigation without fertilizers (12.6 cm) as compared to other drip fertigation. Similar results were noted for curd length of cauliflower. Significantly higher leaf width (11.3 cm) was noticed in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule, while lowest leaf length was observed in T_4: drip irrigation without fertilizers (8.7 cm) over other treatments.

Table 4.6: Effect of drip fertigation levels on root weight cauliflower at 45 DAP and at harvest

Treatment	Root weight 45 DAP (g)	Root weight at harvest (g)
T_1	43.4	64.5
T_2	37.4	58.5
T_3	36.	57.4
T_4	35.4	48.4
Mean	38.1	57.2
SEm	0.3	0.4
$CD_{0.05}$	1.1	1.4

Table 4.7: Effect of fertigation on curd width and curd length

Treatment	Curd width (cm)	Curd length (cm)
T_1	16.4	11.3
T_2	13.9	9.5
T_3	15.1	10.6
T_4	12.6	8.7
Mean	14.5	10.0
SEm	0.5	1.5
$CD_{0.05}$	1.7	0.4

4.2.2 Fresh and dry curd weight of cauliflower

The data on fresh and dry curd weight of cauliflower is depicted in Table 4.8. All the drip fertigation levels had significantly influenced on fresh and dry curd weight of cauliflower. Significantly higher values were recorded under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (684.9 g and 56.8 g) respectively. However significantly lower fresh and dry curd weight were recorded under T_4: drip irrigation without fertilizers (430.4 g and 31.3 g) respectively in comparison with other drip fertigation levels.

Table 4.8: Effect of drip fertigation levels on fresh curd weight and dry curd weight of cauliflower

Treatment	Fresh weight of curd (g)	Dry weight of curd (g)
T_1	684.9	56.0
T_2	561.8	46.8
T_3	562.8	48.1
T_4	430.4	31.3
Mean	559.9	45.5
SEm	2.7	0.8
$CD_{0.05}$	8.4	2.6

4.2.3 Fresh net curd weight and fresh marketable curd weight of cauliflower

Fresh net curd weight and fresh marketable curd weight was significantly influenced by the fertigation treatments (Table 4.9). 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.

Table 4.9: Effect of drip fertigation levels on fresh net curd weight and fresh marketable curd weight

Treatment	Fresh net curd weight (g)	Fresh marketable curd weight (g)
T_1	656.2	890.3
T_2	572.2	786.3
T_3	583.5	803.5
T_4	428.4	650.7
Mean	560.1	782.7
SEm	10.4	12.3
$CD_{0.05}$	32.4	37.8

4.2.4 Curd yield per hectare

The data pertaining to curd yield of cauliflower was influenced by drip fertigation treatments enumerated in Table 4.10. The data revealed that significant differences were observed pertaining curd yield per hectare (t ha^{-1}).

Significantly higher curd yield of cauliflower was observed under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (27.8 t ha^{-1}) while T_4: drip irrigation without fertilizers recorded the lowest curd yield (20.5 t ha^{-1}) over other treatments.

Table 4.10: Effect of drip fertigation levels on curd yield per hectare

Treatment	Curd yield per hectare (t ha^{-1})	Curd yield per plot (kg $plot^{-1}$) (plot size-15 m^2)
T_1	27.88	41.08
T_2	25.43	38.52
T_3	24.45	37.88
T_4	20.52	30.78
Mean	24.57	37.25
SEm	0.23	0.49
$CD_{0.05}$	0.70	1.51

4.3 Effect of fertigation on leaf and curd nutrient content of cauliflower (dry weight basis)

4.3.1 Leaf nutrient content of cauliflower (dry weight basis)

The data on leaf nitrogen, phosphorous and potassium content as influenced by the different fertigation treatments are enumerated in Table 4.11. The results indicated that effect of different drip fertigation treatments on nitrogen, phosphorous and potassium contents in leaf were significant. Significantly higher content of nitrogen, phosphorous and potassium in leaf were observed under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (2.8%, 0.45%, and 1.8%) whereas the treatment T_4: drip irrigation without fertilizers (1.91%, 0.32% and 1.51%) respectively, recorded lower values for nitrogen, phosphorous and potassium contents in leaf.

Table 4.11 Effect of drip fertigation levels on NPK content in leaves (dry weight basis)

Treatment	N content (%)	P content (%)	K content (%)
T_1	2.80	0.45	1.80
T_2	2.46	0.38	1.62
T_3	2.37	0.39	1.61
T_4	1.91	0.32	1.51
Mean	2.37	0.38	1.63
SEm	0.006	0.005	0.007
$CD_{0.05}$	0.02	0.014	0.021

4.3.2 Curd nutrient content of cauliflower (dry weight basis)

The data presented in Table 4.12 revealed that nitrogen, phosphorous and potassium content was influenced by the different fertigation treatments. Significantly higher content of nitrogen, phosphorous and potassium was noticed in curds obtained under treatment T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (1.5%, 0.25% and 1.39%) whereas lower values for these were recorded under treatment T_4: drip irrigation with no fertilizers (1.13%, 0.21% and 1.17%) respectively for nitrogen, phosphorous and potassium contents.

Table 4.12 Effect of fertigation on NPK content in curd (dry weight basis)

Treatment	N content (%)	P content (%)	K content (%)
T_1	1.50	0.25	1.39
T_2	1.28	0.24	1.23
T_3	1.30	0.25	1.23
T_4	1.13	0.21	1.17
Mean	1.30	0.24	1.26
SEm	0.012	0.004	0.005
$CD_{0.05}$	0.038	0.013	0.015

4.4 Benefit cost (B: C) ratio

Benefit cost ratio was worked out for different drip fertigation treatments have been presented in Table 4.13. A perusal of data revealed that maximum gross income was recorded in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule -

3,34,560 (Rs ha^{-1}), followed by T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule-3,05,160 (Rs ha^{-1}). Similarly, net returns were maximum in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (2,48,866 Rs ha^{-1}) followed by T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule-2,17,346 (Rs ha^{-1}). The highest benefit cost ratio was worked out in treatment T_1 which was rated most profitable and cost effective fertigation followed by T_2. Whereas, the lowest benefit cost ratio was recorded under T_4: drip irrigation without fertilizers. Hence, application of nutrients as 100% recommended through drip fertigation using water soluble fertilizers in splits can be used for maximising the cauliflower yield.

Table 4.13 Economic analysis of field experiment

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

CHAPTER – 5 DISCUSSION

The experimental results obtained from the present investigation entitled **"Standardization of drip fertigation levels in mid-season cauliflower (*Brassica oleracea* var. *botrytis* L.)"** have been described in the previous chapter and are discussed in the light of pertinent scientific literature in this chapter.

5.1 Effect of drip fertigation on plant growth attributes of cauliflower

Growth is a multi-dimensional web of many parameters. It is a phenotypic expression with respect to nutrient status, provided all other conditions are favourable. Vegetative growth in most of the crop is in direct proportion to nutrient supply to that crop. In the present experiment, growth characters in terms of plant height, number of leaves and dry weight of cauliflower at different stages of the crop growth were significantly influenced by the drip fertigation.

The plant height showed a linear trend of growth during different stages of the observation (Fig.5.1 and Table 4.1). The plant height was recorded to be the highest in T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule followed by T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule at 45 DAT and at harvest. It might be due to timely availability of nutrients supplied through fertigation with suitable proportion of fertilizers. T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule and $T_{3:}$ drip irrigation with 100% conventional fertilizer (soil application) had miniscule plant height difference between them and T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule is more efficient as it uses less fertilizers compared to $T_{3:}$ drip irrigation with 100% conventional fertilizer (soil application). Lowest values for plant height were recorded under T_4 at 45 DAT and at harvest respectively, where drip irrigation without fertilizers was given. These results obtained were in accordance with the results of Kadam *et al.* (2006) in cauliflower cv. Golden 80 from Rahuri, Maharashtra.

The prerequisite for getting higher yield in cauliflower crop is higher total dry matter production and its distribution to the various plant parts. The total dry matter production of cauliflower differed significantly due to various fertigation treatments. It was significantly higher with T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule over control in all crop growth stages. In micro irrigation system, the higher plant dry matter may be attributed to the profused vegetative growth on account of optimum soil moisture and nutrient supply, in the rhizosphere during the cauliflower crop growth period. These results are in close confirmation with Jadhav (2015) in onion crop from Rahuri, Maharashtra.

The number of leaves in cauliflower was significantly higher under 100% of recommended fertilizer (T_1) as compared to other drip fertigation treatments. Treatment T_1 had recorded highest number of leaves under which water soluble fertilizers were used for drip fertigation where in T_4 no fertilizers were used. The higher number of leaves may be attributed to balanced nutrition, better water and nutrients utilization which have resulted in more vegetative growth. The results were in accordance with the findings of Yanglem and Tumbare (2014) in cauliflower, stated that the increase in number of leaves might be due to the fact that that nitrogen with synthesized carbohydrates was metabolized into amino acids and proteins, which allowed the plants to grow faster and produce more number of leaves in cauliflower.

The data on leaf width and leaf length recorded under different fertigation treatments are presented in Table 4.3. It is evident that, drip fertigation with 100% recommended dose (T_1) with water soluble fertilizers significantly influenced the leaf length and leaf width. The lowest values were recorded under treatment T_4 where no fertilizers were provided. The higher leaf width and length is attributed to better utilization of nutrients which had resulted in more vegetative growth and higher photosynthetic rate. It was also due to increased cell enlargement because of maintenance of higher turgour pressure in the plants (Usharani, 2008). These results were also in accordance with the findings of Singh *et al*. (2000) in onion and Deolankar (2004).

The data presented in Table 4.5 and 4.6 indicated that different fertigation treatments markedly influenced the root length and root weight of cauliflower. Fertigation level T_1 comprising of drip fertigation with 100% recommended dose of fertilizers recorded higher root length and root weight, lowest values for root length and root weight was recorded under fertigation level T_4 where no fertilizers were used at 45 days after transplanting and at harvest, respectively. The higher root length and root weight attributed to better availability of nutrients and efficient uptake by the roots from soil.

5.2 Effect of drip fertigation on curd and yield attributes of cauliflower

Yield is an important character which is responsible for the commercial viability and acceptability of a variety and is one of the most important traits attaining highest consideration in research programmes. Yield is the net result of various interactions viz., soil characters, weather parameters, leaf area and various metabolic and biochemical interactions taking place during crop growth. Curd yield is also influenced by dry matter accumulation in different parts especially attributes like curd weight, curd length and curd width which are the product of interactions of above characters.

The data presented in Table 4.8 and Fig 5.4 indicates that different fertigation treatments markedly influenced the fresh and dry weight of cauliflower curd. Fertigation treatment T_1 comprising of drip fertigation with 100% recommended dose of fertilizers exhibited highest fresh and dry curd weight, as compared to other levels. 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).The treatment with no fertilizers T_4 had recorded lowest values of fresh and dry weight of curd. 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 which resulting in luxurious crop growth and thereby enhancing the curd weight.

Yield and yield components (Table 4.9 and 4.10 and Fig. 5.5 and 5.6) of cauliflower varied significantly among various treatments. Significantly higher curd yield was recorded with drip fertigation with 100% recommended dose of fertigation as per schedule over control treatment *i.e.*, drip irrigation with no fertigation. However, it was on par with drip irrigation with $T_{3:}$ drip irrigation with 100% conventional fertilizer (soil application). The T_1 yield was higher by 135 % over control (Fig. 5.5).

Higher values for net curd weight and marketable curd weight was recorded under T_1 whereas, the lowest values were recorded under T_4 (Table 4.10 and Fig 5.6). The increase in curd width and yield was as a result of increased fertigation levels. Significantly higher yield parameters under T_1 may be attributed to much better water and nutrient utilization. Furthermore, under the 100% recommended dose of fertigation treatments nutrients were applied in 20 split doses such fractionated supplies in optimum nutrient concentration might have met the nutrient requirement of cauliflower at various growth stages thus leading to higher curd weight and yield. The results were in agreement with the findings of Kadam *et al*. (2006) in cauliflower cv. Golden 80, Singla *et al*. (2007) in cauliflower, Guler *et al*. (2008) in cauliflower. Yanglem and Tumbare (2014) in cauliflower have also made the similar findings and attributed to such effect at higher fertigation level, crop meet out its nutrient requirement at respective growth stage which lead to luxuriant growth and thereby enhances the yield levels in cauliflower.

5.3 Effect of fertigation on leaf and curd nutrient content of cauliflower

The total uptake of nutrients was found to be influenced significantly due to different treatments. The effect of different fertigation treatments on leaf nutrient content are presented in Table 4.11 and Fig 5.7. It is evident that fertigation levels exerted a significant effect on the leaf nutrient content. The application of fertilizer as recommended dose (T_1) recorded significantly higher leaf nitrogen, phosphorous and potassium content (2.8%, 0.45%, and 1.8%) and lower values for leaf nitrogen, phosphorous and potassium content were observed under T_4 (1.91%, 0.32% and 1.51%). The higher leaf nitrogen, phosphorous and potassium content may be due to increased uptake of these nutrients, owing to precise frequent and direct application of fertilizers through drip fertigation into the root zone which led to minimum losses. These observations are in agreement with the findings of Ramachandrappa *et al*. (2010) in chilli, Rajaraman *et al*. (2010) in coriander and Fontes *et al*. (2014) in tomato.

The data presented in Table 4.13 and Fig 5.8 on the status of nitrogen, phosphorous and potassium content in cauliflower curds revealed that higher NPK content was registered with the treatment T_1 (100% RD). Significantly higher content of nitrogen, phosphorous and potassium was noticed in curds obtained under treatment T_1 (1.5%, 0.25% and 1.39%)

whereas lower values for these were recorded under treatment T_4 (1.13%, 0.21% and 1.17%). The increase in total nutrient uptake with 100% of recommended dose of fertigation as per schedule was mainly due to weekly supplying of nutrients through fertigation according to the needs of the crop growth stages. This could be also due to increase in plant height, number of leaves per plant, leaf area, dry matter production per plant etc., In case of treatment of drip irrigation 100% conventional fertilizer (soil application) the total nutrient uptake was decreased, it may be due to the fact that the loss of nutrients due to leaching. Different fertigation levels exerted variable impact on the curd nitrogen, phosphorous and potassium content. Patil and Das (2015) in capsicum also reported increased uptake of nutrients with fertigation.

5.4 Benefit cost (B: C) ratio

In the present investigation, treatment comprising 100% of recommended dose of fertilizer (T_1) registered highest B:C ratio (2.8), closely followed by T_2 with 75% of recommended dose of fertilizer and T_3:drip irrigation with 100% conventional fertilizer whereas, lowest B:C ratio was recorded under T_4 with no fertilizer (Table No 4.13). Comparatively higher B:C ratio under T_1 may be due to higher marketable yield and nutrient availability. The treatments T_2 and T_3 were also found to be superior which may also be attributed to higher yields and favourable soil environment. But under T_1 cost of application of application fertilizers was negligible and nutrients losses are minimal since fertigation was given in split doses. These results are in agreement with those of Fanish and Muthukrishnan (2011) in radish, Ramniwas *et al*. (2013) in guava and Raj *et al*. (2015) in cotton.

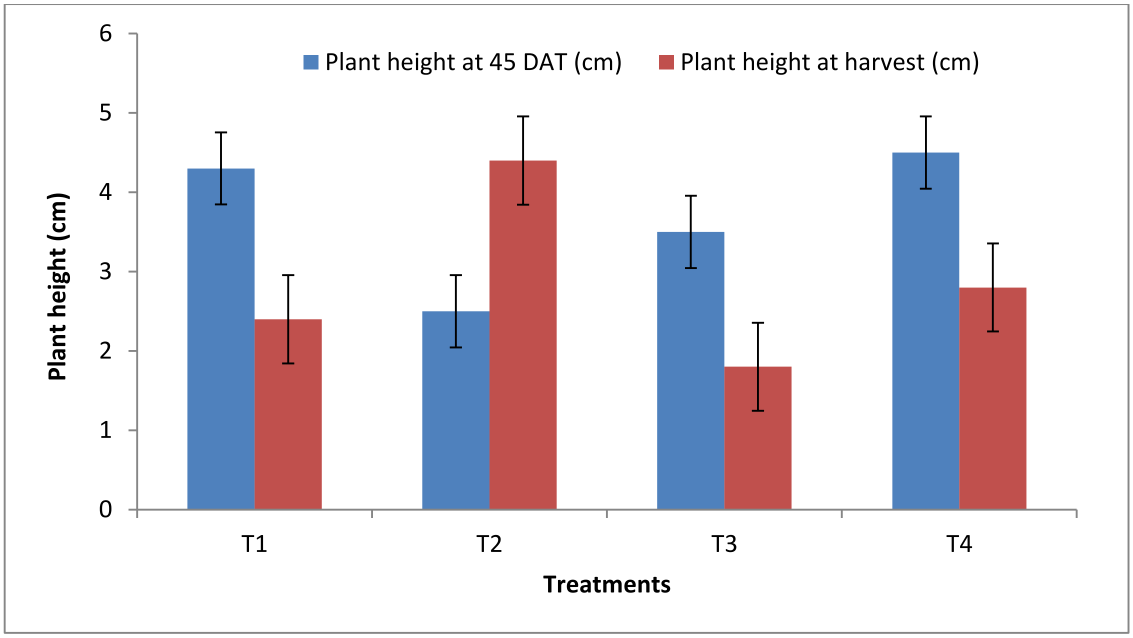

Fig 5.1: Plant height (cm) under different fertigation treatments at 45 DAT and at harvest

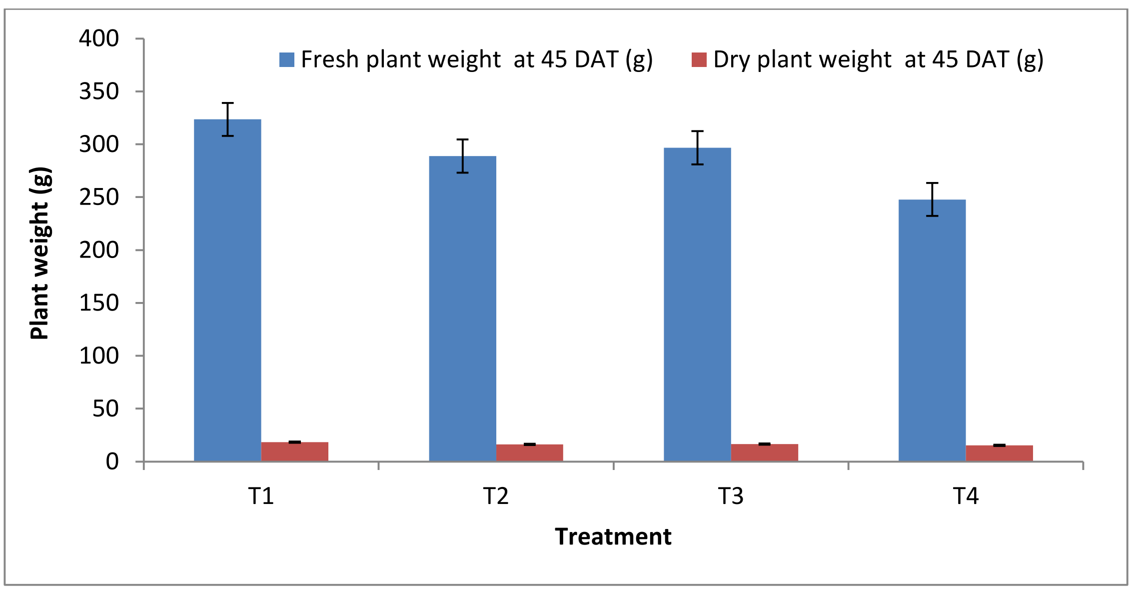

Fig 5.2: Fresh and dry weight of plant under different fertigation treatments at 45 DAT

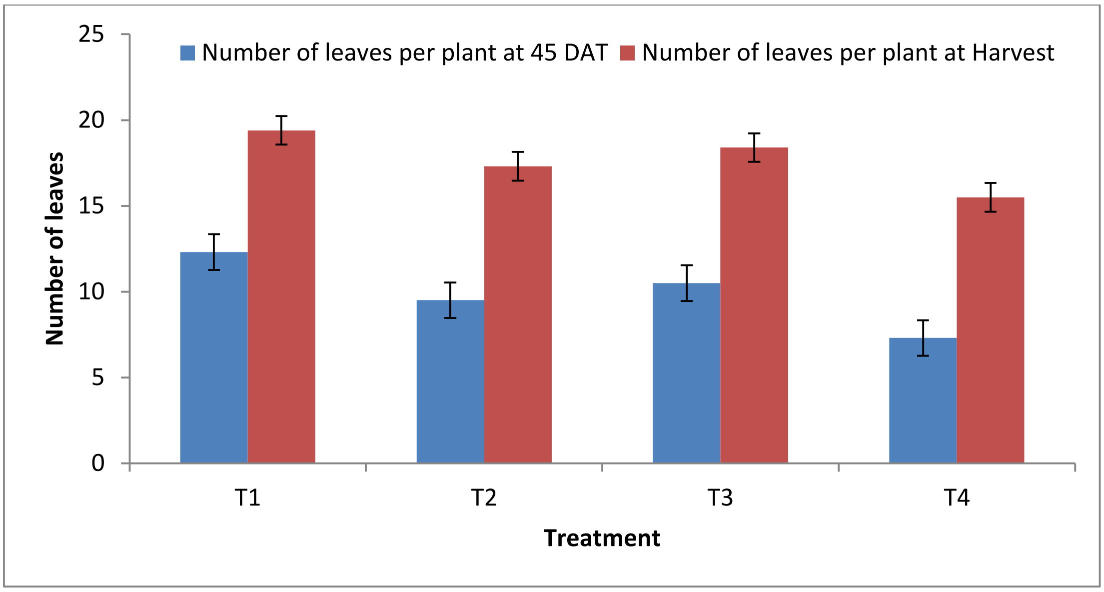

Fig 5.3: Number of leaves per plant under different fertigation treatments at 45 DAP and at harvest

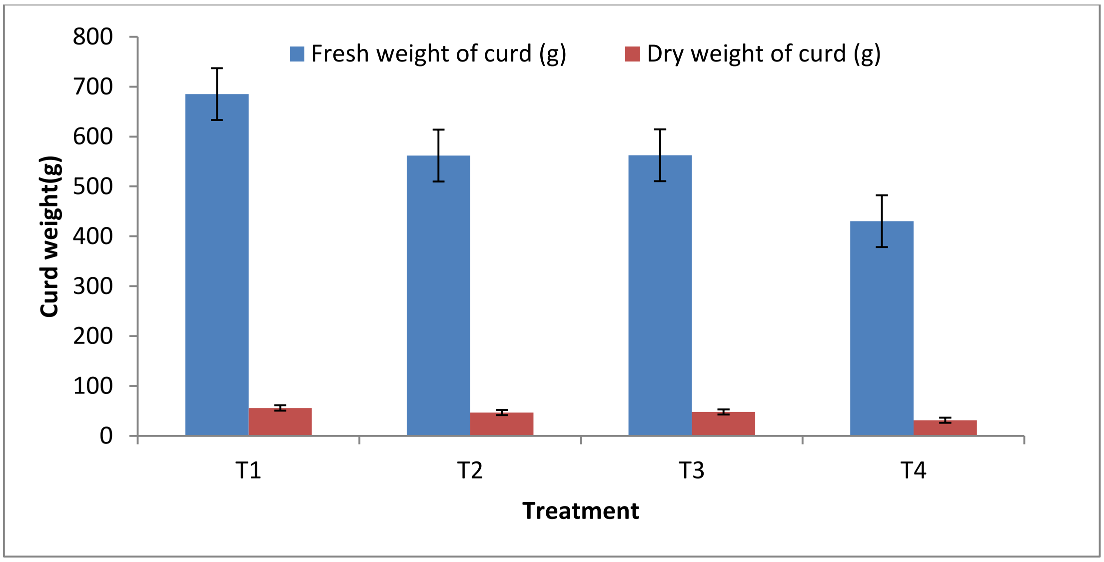

Fig 5.4: Effect of drip fertigation levels on fresh and dry weight of curd

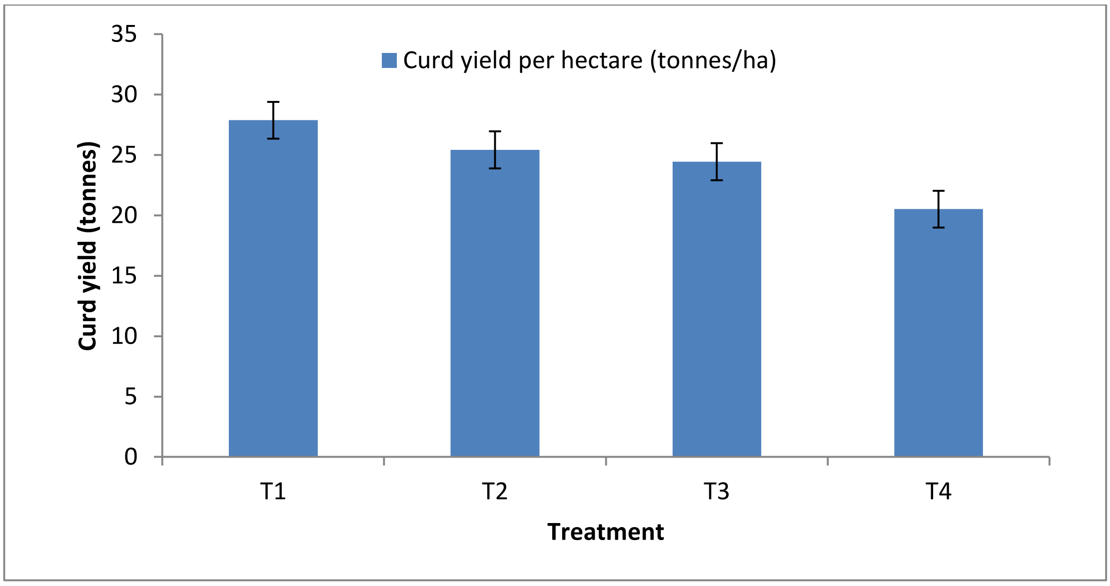

Fig 5.5: Effect of drip fertigation levels on Curd yield per hectare

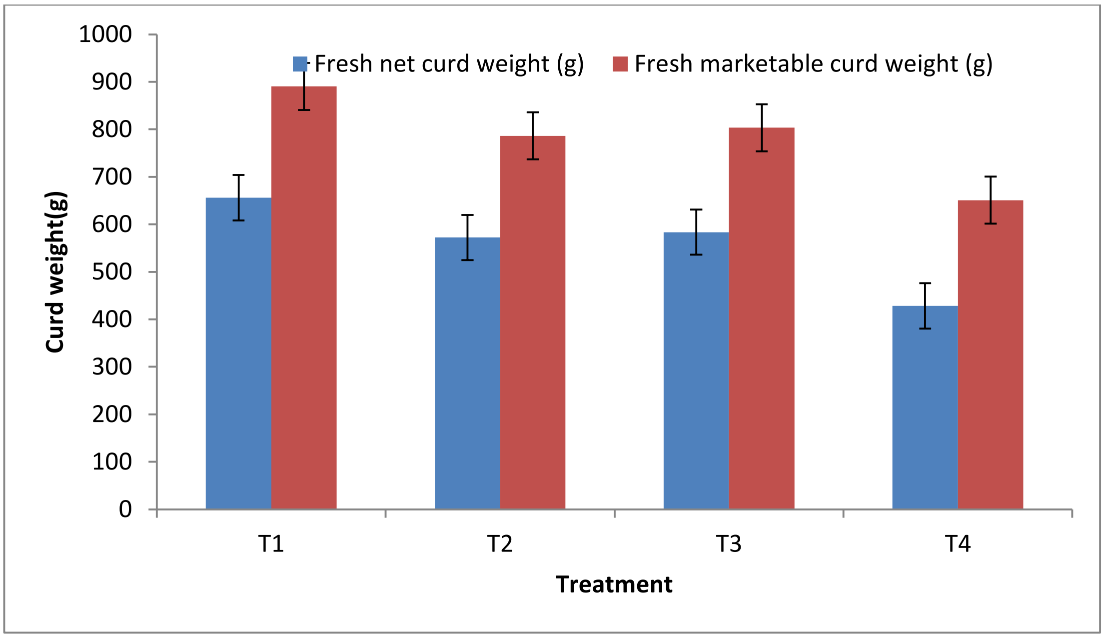

Fig 5.6: Effect of drip fertigation levels on net curd weight and marketable curd weight

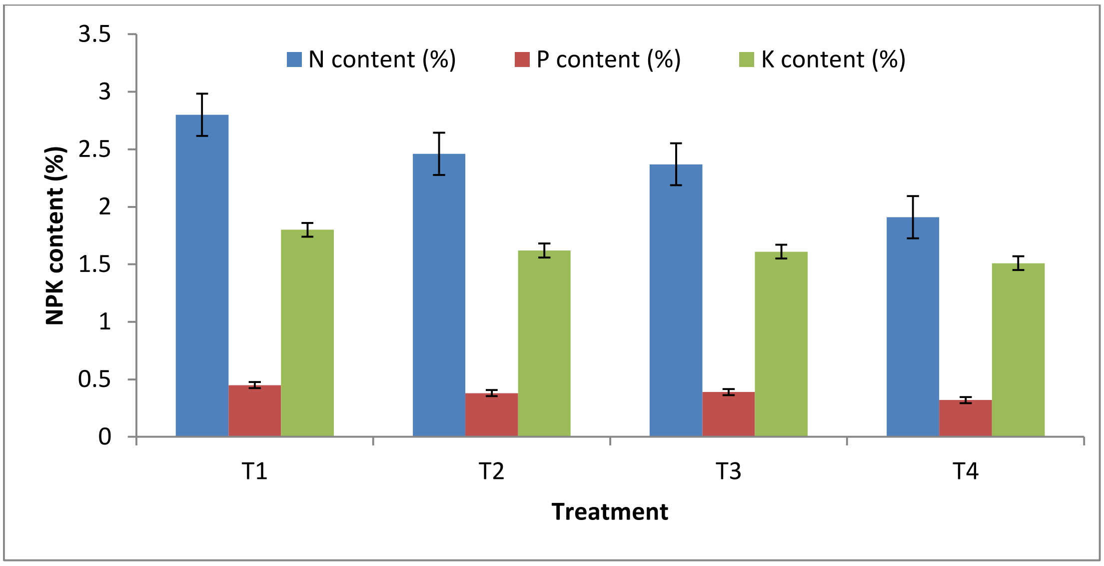

Fig 5.7: Effect of drip fertigation levels on NPK content (%) in leaves

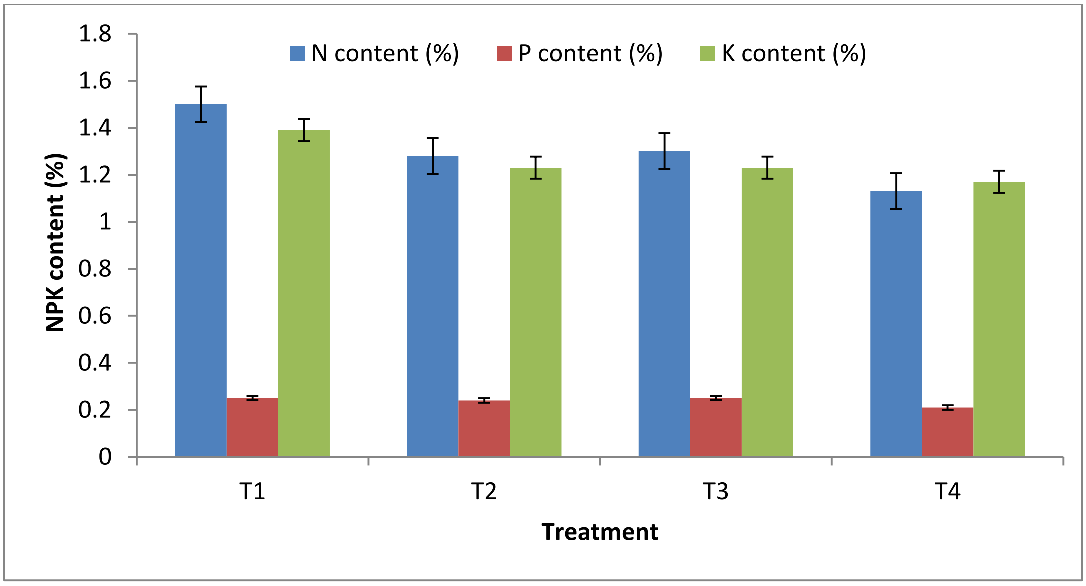

Fig.5.8: Effect of drip fertigation levels on NPK content in curd

CHAPTER – 6 SUMMARY AND CONCLUSION

Under suitable agro climatic condition mineral nutrition (mainly major nutrients like N, P and K) is the main factor which influences the growth and yield of cauliflower to a greater extent. Curd yield and its quality are greatly influenced by adequate supply of nutrients, particularly N, P and K. So, judicial application of nutrients will help to obtain higher yield. Therefore, it is essential to standardize the fertigation schedule for transplanted cauliflower.

Fertilizer is one of the most important inputs, which needs to be utilized most judiciously and efficiently. Fertigation assures application of nutrients directly into the wetted volume of soil below the emitter where root activity is mainly concentrated. This not only results in higher uptake of nutrients but also reduces leaching and other losses, thereby enhancing their use efficiency. Fertigation consequences in cauliflower, one of the important vegetable crop, have not been established so far northern plain of India particularly in mid-maturity group.

In view of this a field experiment was carried out at experimental Farm of Water technology Centre, Indian Agricultural Research Institute, New Delhi on cauliflower cv. Pusa Sharad to study the **“Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea* var. *botrytis* L.)”** during rabi season 2018-19

The experiment was laid out in Randomized Block Design with four treatments and five replications. One month old seedlings were transplanted 21-09-2018 at a spacing of 60 cm x 45 cm in twenty plots of 5m x 3m dimension. Fertigation was done through venturi in 20 equal split applications at 3-4 days intervals, starting *w.e.f.* 21-09-2019 of experimental year and continued till 8-11-2019. The water soluble fertilizer (Urea, phosphate and SOP) was used for fertigation. The study aimed at to evaluate the effect of drip fertigation treatments on plant, yield and quality characteristics of cauliflower and benefit cost ratio.

Salient findings emerged are summarized here under:

Drip fertigation influence on plant growth, yield and quality in cauliflower.

- ❖ Drip fertigation had a significant effect on plant height of cauliflower. Higher plant height was observed under T_1 (100% RD) while lowest was observed under T_4.
- ❖ Drip fertigation had significant effect on number of leaves of cauliflower. Different levels of fertigation had variable impact on number of leaves with treatment T_1 (100% RD) recording highest number of leaves.
- ❖ Drip fertigation with 100% recommended dose of fertilizers had significant impact on the leaf length and leaf width of cauliflower. Highest leaf length and leaf width was observed under T_1 while lowest was observed under T_4.
- ❖ Fresh and dry weight of the plant significantly differed with the fertigation treatments. Higher fresh and dry plant weight was obtained under T_1 whilst lowest fresh and dry weight was obtained under T_4.
- ❖ Significant influence of drip fertigation was observed on fresh and dry curd weight of cauliflower. Fertigation with 100% RD had recorded higher fresh and dry curd weight while treatment where no fertilizers were used recorded the lowest fresh and dry curd weight.
- ❖ Root length and root weight was significantly influenced by drip fertigation treatments. Significant and higher root length was recorded under treatment T_1 (100% RD) while lowest was observed under T_4.
- ❖ Yield parameters i.e., curd width, curd length and curd yield per hectare were influenced significantly by the drip fertigation treatments. Higher curd width and curd yield was obtained under drip fertigation where 100% RD of fertilizers were used. Lower values were recorded under control.
- ❖ Different levels of fertigation had variable impacts on net curd weight and marketable curd weight. Fertigation with 100% recommended dose, significantly increased net curd weight and marketable curd weight.

Leaf and curd nutrient content

- ❖ Fertigation significantly increased the leaf nitrogen, phosphorous and potassium content. Significantly higher leaf N, P, K content was recorded with 100% recommended dose. While they were lowest in control where no fertilizers were used.

- Drip fertigation had significant effect on curd nitrogen, phosphorous and potassium contents. The higher content of nitrogen, phosphorous and potassium were noticed in curds obtained under treatment T_1 (1.5%, 0.25% and 1.39%) whereas lower values for these were recorded under treatment T_4 (1.13%, 0.21% and 1.17%).

Benefit Cost Ratio

- Among the different drip fertigation levels tried, highest benefit cost ratio was noticed under 100% recommended dose i.e., under treatment T_1. Lowest benefit cost ratio was noticed under T_4. Therefore, application of nutrients as recommended dose through drip fertigation can be used for maximizing cauliflower growth parameters and yield.

CONCLUSION

On the basis of the study, it may be concluded that different levels of fertigation had variable impact on yield and quality characteristics of cauliflower. However, the difference between fertigation with 100% recommended dose and other treatments were appreciable. The application of 76: 46: 83 kg N_2: P_2O_5: K_2O per hectare through fertigation recorded highest benefit cost (B:C) ratio of 2.9. Therefore, the study suggests that application of recommended dose of fertilizer through drip irrigation in 20 splits leads to higher curd yield which can be used for production of mid-maturity group of cauliflower in northern plains of India.

Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea* var. *Botrytis* L.)

ABSTRACT

A field experiment entitled **Standardization of drip fertigation levels in mid-season Cauliflower (*Brassica oleracea var. botrytis* L.)** was conducted during rabi 2018-2019 at experimental farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi. The experiment was carried out under open condition in a randomized block design with four treatments namely, T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule, T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule, T_3: drip irrigation with 100% conventional fertilizer (soil application), T4: drip irrigation without fertilizers (control), replicated four times.

The results of the study revealed that the highest values for plant growth attributes *viz.*, plant height, number of leaves, leaf length and width, fresh plant weight, dry plant weight, root length and root weight was obtained under treatment T_1. The data revealed that significant differences were observed pertaining to parameters such as curd width and curd length which were highest under T_1. Other curd parameters like fresh curd weight, dry curd weight, net curd weight, marketable curd weight was also higher under T_1 where 100% RD of fertilizers were used. Significantly higher curd yield of cauliflower was observed under T_1: drip fertigation with 100% recommended dose of fertilizers as per schedule (27.88 t ha^{-1}). Leaf nutrient content analysis also revealed that higher leaf nitrogen, phosphorous and potassium content was observed under T_1 and curd nutrient content was also higher under the same treatment where 100% RD of fertilizers were given. Highest benefit cost ratio was noticed under 100 per cent recommended dose i.e. under treatment T_1 (2.8). Lowest benefit cost ratio was noticed under T_4 (2.02). Therefore, application of nutrients as recommended dose through drip fertigation can be used for maximizing cauliflower growth parameters and yield.

Key words: Cauliflower, drip fertigation, growth parameters, yield, B:C ratio

मध्य मौसम फूलगोभी में ड्रिप फर्टिगेशन स्तर का मानकीकरण (ब्रैसिका ओलेरेसिया किस्म बोट्राटिस एल)

सारांश

रबी वर्ष 2018–19 के दौरान जल प्रौद्योगिकी केन्द्र, भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली स्थित भूमि पर 'मध्य मौसम फूलगोभी (ब्रैसिका ऑलेरासिया बॉट्राटिस एल) में ड्रिप फर्टिगेशन स्तर के मानकीकरण' नामक शीर्षक से एक प्रयोग संचालित किया गया। इस प्रयोग में चार प्रकार के उपचार यादृच्छिक रूप से ब्लॉक बनाकर खुले वातावरण में किया गया, जिसमें टी1ः शेड्यूल के अनुसार उर्वरक के 100 प्रतिशत अनुशंसित खुराक के साथ ड्रिप फर्टिगेशन, टी2ः शेड्यूल के अनुसार उर्वरके के 75 प्रतिशत अनुशंसित खुराक के साथ ड्रिप फर्टिगेशन, टी3ः 100 प्रतिशत पारंपरिक उर्वरक (मृदा अनुप्रयोग) के साथ ड्रिप फर्टिगेशन टी4ः उर्वरक (नियंत्रण) के बिना ड्रिप फर्टिगेशन, को चार बार दोहराया गया।

अध्ययन के परिणामों से पता चला कि पौधों की वृद्धि के लिए उच्चतम मूल्य अर्थात् पौधों की ऊँचाई, पत्तियों की संख्या, पत्ती की लम्बाई और चौड़ाई, स्वस्थ पौधों का भार, सूखे पौधों का भार, जड़ की लम्बाई और जड़ का भार टी1 उपचार के अंतर्गत प्राप्त किया गया था। आंकड़ों से पता चला कि मापदण्डों से सम्बन्धित आंकड़ों जैसे फूलों की चौड़ाई एवं लम्बाई में अंतर देखे गए जो सार्थक रूप से टी$_1$ के अंतर्गत उच्चतम थे। अन्य मापदंड यथा स्वस्थ फूलों का भार, सूखा भार, शुद्ध फूलों का भार एवं विपणन योग्य फूलों का भार भी टी1 उपचार के अंतर्गत अधिक था जहॉ उर्वरक के 100 प्रतिशत अनुशंसित खुराक के साथ ड्रिप फर्टिगेशन किया गया था। उल्लेखनीय रूप से टी$_1$ ड्रिप फर्टिगेशन के साथ जहॉ उर्वरक के 100 प्रतिशत अनुशंसित खुराक का प्रयोग किया गया था, फूलगोभी की उच्च फूलों की पैदावार (27.88 टन हेक्टे0^{-1}) प्राप्त हुई। साथ ही साथ पत्ती में पोषक तत्व सामग्री के विश्लेषण से पता चला कि टी$_1$ ड्रिप फर्टिगेशन के तहत उच्चतम नाईट्रोजन, फॉस्फोरस एवं पोटेशियम की मात्राएं पायी गयी। टी$_1$ के अंतर्गत ही उच्चतम लाभ लागत अनुपात (2.8) देखा गया जबकि टी4 के अंतर्गत सबसे कम लाभ लागत अनुपात (2.02) देखा गया । इसलिए पोषक तत्वों की अनुशंसित मात्राा के साथ ड्रिप फर्टिगेशन का प्रयोग फूलगोभी के उच्चत्तम विकास व उपज को अधिकतम करने के लिए किसान के खेत पर भी किया जा सकता है।

मुख्य शब्दः फूलगोभी, ड्रिप फर्टिगेशन, विकास मापदंडों, उपज, बीःसी अनुपात

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ANNEXURE I

Table 1. Cost of cultivation fort T_1: drip fertigation with 100% RD of fertilizers (₹ ha^{-1})

SR. NO.	Operation	Unit	Rate (₹)	Cost ha^{-1} (₹)
1	Nursery raising			
	Nursery preparation	2 man-day	300	600
	Seed	500 g	2500/kg	1250
	Seed treatment and drenching (Bavistin)	500g	1060	530
2	Field preparation			
	Disc harrowing	5 tractor hr	250/hr	1250
	Rotovator	5 tractor hr	250/hr	1250
3	Uprooting and transplanting	15 man-day	300	4500
4.	Bunding	10 man-day	300	3000
5.	Hand weeding(2 times)	50 man-day	300	15000
6.	Fertilizer and manures			
	Green manure	-	-	2000
	Urea	165kg/ha	552/q	910
	Urea phosphate	104kg/ha	7600/q	7904
	SOP	166kg/ha	1600 /q	2656
7.	Pesticide			
	Indoxicarb	100ml/ha	690/200ml	340
	Confidor	500 ml/ha	352/250 ml	704
	Spraying	8 man-day	300	2400
8.	Irrigation			
	Pumping cost (number of irrigation)	11	500	5500
	Drip installation cost			26200
9.	Harvesting and transportation	30 man-days	300	9000
10.	Rental value of land	4 month	800	3200
11.	Miscellaneous			2000
	Total cost of cultivation			**88,694**

Cost of cultivation = 88,694 (₹ ha^{-1})
Gross returns = 3,34,560 (₹ ha^{-1})
Net returns = 2,48,866 (₹ ha^{-1})
Net B: C Ratio =2.80

Table 2. Cost of cultivation fort T_2: drip fertigation with 75% recommended dose of fertilizers as per schedule (₹ ha^{-1})

SR. NO.	Operation	Unit	Rate (₹)	Cost ha^{-1} (₹)
1	Nursery raising			
	Nursery preparation	2 man-day	300	600
	Seed	500 g	2500/kg	1250
	Seed treatment and drenching (Bavistin)	500g	1060	530
2	Field preparation			
	Disc harrowing	5 tractor hr	250/hr	1250
	Rotovator	5 tractor hr	250/hr	1250
3	Uprooting and transplanting	15 man-day	300	4500
4.	Bunding	10 man-day	300	3000
5.	Hand weeding(2 times)	50 man-day	300	15000
6.	Fertilizer and manures used			
	Green manure	-	-	2000
	Urea	123kg/ha	552/q	678
	Urea phosphate	78kg/ha	7600/q	5928
	SOP	124kg/ha	1600 /q	1984
7.	Pesticide			
	Indoxicarb	100ml/ha	690/200ml	340
	Confidor	500 ml/ha	352/250 ml	704
	Spraying	8 man-day	300	2400
8.	Irrigation			
	Pumping cost (number of irrigation)	11	500	5500
	Drip installation cost			26200
9.	Harvesting and transportation	30 man-days	300	9000
10.	Rental value of land	4 month	800	3200
11.	Miscellaneous			2000
	Total cost of cultivation			**87,814**

Cost of cultivation = 87,814 (₹ ha^{-1})
Gross returns = 3,05,160 (₹ ha^{-1})
Net returns = 2,17,346 (₹ ha^{-1})
Net B: C Ratio = 2.47

Table 3. Cost of cultivation fort T_3: drip irrigation with 100% convention fertilizer (₹ ha^{-1})

SR. NO.	Operation	Unit	Rate (₹)	Cost ha^{-1} (₹)
1	Nursery raising			
	Nursery preparation	2 man-day	300	600
	Seed	500 g	2500/kg	1250
	Seed treatment and drenching (Bavistin)	500g	1060	530
2	Field preparation			
	Disc harrowing	5 tractor hr	250/hr	1250
	Rotovator	5 tractor hr	250/hr	1250
3	Uprooting and transplanting	15 man-day	300	4500
4.	Bunding	10 man-day	300	3000
5.	Hand weeding(2 times)	50 man-day	300	15000
6.	Fertilizer and manures used			
	Green manure	-	-	2000
	Urea	260kg/ha	552/q	1435
	SSP	375kg/ha	990 /q	3715
	MOP	100kg/ha	1390 /q	1390
7.	Pesticide			
	Indoxicarb	100ml/ha	690/200ml	340
	Confidor	500 ml/ha	352/250 ml	704
	Spraying	8 man-day	300	2400
8.	Irrigation			
	Pumping cost (number of irrigation)	11	500	5500
	Drip installation cost			26200
9.	Harvesting and transportation	30 man-days	300	9000
10.	Rental value of land	4 month	800	3200
11.	Miscellaneous			2000
	Total cost of cultivation			**85,764**

Cost of cultivation = 85,764 (₹ ha^{-1})
Gross returns = 2,93,400 (₹ ha^{-1})
Net returns = 2,07,636 (₹ ha^{-1})
Net B: C Ratio = 2.42

Table 4. Cost of cultivation fort T4: drip irrigation without fertilizer (₹ ha^{-1})

SR. NO.	Operation	Unit	Rate (₹)	Cost ha^{-1} (₹)
1	Nursery raising			
	Nursery preparation	2 man-day	300	600
	Seed	500 g	2500/kg	1250
	Seed treatment and drenching (Bavistin)	500g	1060	530
2	Field preparation			
	Disc harrowing	5 tractor hr	250/hr	1250
	Rotovator	5 tractor hr	250/hr	1250
3	Uprooting and transplanting	15 man-day	300	4500
4.	Bunding	10 man-day	300	3000
5.	Hand weeding(2 times)	50 man-day	300	15000
6.	Fertilizer and manures used			
	Green manure	-	-	2000
	Urea	0kg/ha	552/q	0
	SSP	0 kg/ha	990 /q	0
	MOP	0 kg/ha	1390 /q	0
7.	Pesticide			
	Indoxicarb	100ml/ha	690/200ml	340
	Confidor	500 ml/ha	352/250 ml	704
	Spraying	8 man-day	300	2400
8.	Irrigation			
	Pumping cost (number of irrigation)	11	500	5500
	Drip installation cost			26200
9.	Harvesting and transportation	30 man-days	300	9000
10.	Rental value of land	4 month	800	3200
11.	Miscellaneous			2000
	Total cost of cultivation			**79,224**

Cost of cultivation = 79,224 (₹ ha^{-1})
Gross returns = 2,46,240 (₹ ha^{-1})
Net returns = 1,60,476 (₹ ha^{-1})
Net B: C Ratio = 2:02

ANNEXURE II

Table 1. Irrigation schedule for the field experiment

Sl. Number	Date	Duration (minutes)
1	21-Sept	26
2	24- Sept	26
3	27- Sept	26
4	31- Sept	28
5	3-Oct	28
6	6- Oct	28
7	9- Oct	28
8	12- Oct	29
9	16- Oct	29
10	20- Oct	29
11	25- Oct	29
12	30- Oct	29
13	4-Nov	29
14	8- Nov	28
15	10- Nov	28
16	13- Nov	28
17	16- Nov	28
18	19- Nov	26
19	22- Nov	26
20	25- Nov	26