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Optimization of Nitrogen Dose through Fertigation in Cauliflower under Drip Irrigation

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ABSTRACT

Proper management of nitrogenous fertilizers is of paramount importance for economical crop production and sustainable soil-water-atmosphere ecosystem. The present study was conducted to examine the effect of different nitrogen fertigation levels on cauliflower crop through drip irrigation. The nitrogen fertilizer (urea) was applied in 35 equal doses with irrigation water applied at alternate day through drip irrigation system. Soil moisture in the soil profile of different treatments was recorded at fortnight interval. The observed moisture content tended to decrease with increase in radial distance from the drip lateral at all soil depths. The soil moisture tended to decrease with increase in soil depth at all radial distances, throughout the soil profile, during whole crop period, in all the treatments. The cauliflower yield with N-fertigation of 90 kg ha^{-1} (75% of Recommended dose of N), 120 kg ha^{-1} (100% RDN) and 150 kg ha^{-1} (125% RDN) was found to be 221 q ha^{-1}, 231 q ha^{-1} and 234 q ha^{-1} respectively. The water use efficiency (WUE) was calculated to be 80.7 kg m^{-3}, 84.2 kg m^{-3} and 85.4 kg m^{-3} under 75% RDN, 100% RDN and 125 % RDN respectively. The nitrogen use efficiency (NUE) was found to be 245.6 kg kg^{-1}, 192.2 kg kg^{-1} and 156 kg kg^{-1} under 75% RDN, 100% RDN and 125% RDN respectively. The increased N-fertigation level did not improve the cauliflower yield and WUE much but reduced the NUE to a great extent.

Keywords Cauliflower, Drip irrigation, Fertigation, Nutrient-use-efficiency, Water-use- efficiency.

INTRODUCTION

Water and nutrients are most vital input for successful crop production. With increased competition for water resources among various sectors, the pressure for the most efficient use of water in agriculture is increasing. Drip irrigation, which has an irrigation efficiency of more than 90%, is one of the most modern and effective irrigation techniques. Comparing the drip irrigation technique to the conventional irrigation method, the crop production is often increased by 25–30% and irrigation water is also saved by 50–60% (Yang *et al.* 2023). Drip irrigation, due to its capability to apply small and frequent amounts of fertilizers dis-

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solved in irrigation water (fertigation), also promises to apply fertilizers with high fertilizer-use-efficiency. In fertigation, nutrient-use- efficiency could be as high as 90% compared to 40–60% in conventional method mainly due to decreased leaching of nutrients under drip irrigation. Fertigation enables adequate supplies of water and nutrients to meet crop nutrient demand with precise timing and uniform distribution (Ashrafi *et al.* 2020). Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses. The primary benefits of fertigation are labor savings, accurate timing of water and nutrient application and uniform distribution of nutrients. Nitrogenous fertilizers constitute the largest share among all NPK fertilizers consumed in India. The total N fertilizers consumed in India was about 17628 thousand tonnes (65%) out of total NPK fertilizers used in India (Anonymous 2019a). The total import of N fertilizers in India is about 4700 thousand tonnes per year. The government of India has the provision of subsidy of Rs 2183.5 per bag of 45 kg urea (Anonymous 2022), which drains about Rs 23000 crore every year out of our country. Apart from that, the irrational uses of N fertilizers cause the ground water pollution and also contribute to the global warming. Therefore, it becomes imperative to use the N fertilizer in a most judicious manner. Cauliflower (*Brassica oleracea*) is an important, remunerative and nutritive vegetable grown in India. It works as anti-cancer agent. It promotes heart health, lower cholesterol levels. The area under cauliflower cultivation in India is about 465000 ha with a production 9083 mt (Anonymous 2019b). Nitrogen (N) is an important ingredient in plant growth and is required in relatively large amounts in readily accessible forms. On the other hand, N is subjected to losses if not managed effectively due to its solubility, mobility and volatility. In order to optimize the level of N dose in cauliflower under drip, we need to know the response of the crop under different N doses through drip irrigation. The ability of drip irrigation to apply water in small quantity, supply the plant nutrients precisely offer an opportunity for the maximization of crop production along with efficient use of N fertilizers. The present study was planned to study the response of different levels of nitrogen application on cauliflower crop and to work out suitable nitrogen fertigation dose for cauliflower crop under drip irrigation.

MATERIALS AND METHODS

The present study entitled "Optimization of nitrogen dose through fertigation in cauliflower under drip irrigation" was conducted by Department of Soil and Water Engineering at the research farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during November to February of 2021–22. The experiment was conducted with three nitrogen fertigation levels viz N_1 = 75% RDN (Recommended dose of nitrogen), N_2=100% RDN and N_3 = 125% RDN in micro-plots (1.8 m × 4.5 m). The experimental site is located in the North-western part of Haryana at 29º15′37.60″ N (latitude) and 75º69′61.88″ E (longitude) with an average elevation of about 215.2 m above the mean sea level (MSL). The meteorological parameters (pan evaporation, pan coefficient and rainfall) for the experimental period, used in the study, were collected from the Department of Agricultural Meteorology, COA, CCS Haryana Agricultural University, Hisar. The physical and chemical properties of the soil of the experimental area are given in Table 1.

Cauliflower seeds (variety Snowball–16) were sown, at the seed rate 400 g ha^{-1}, on seed beds of dimensions 3 m × 1 m, prepared for nursery raising, in rows, maintaining a row to row spacing of 10 cm. After sowing, seeds were covered with compost and light irrigation was applied every day till germination of seeds, using micro sprinklers. After the germination of seeds, water was supplied timely as per requirement. Plants got ready for transplanting in about 40 days after sowing. The field was ploughed three to four times with harrow every time followed by planking and thereafter, the rotavator was used to bring the field to a fine tilth. FYM @ 20 t/acre, 100% of phosphorus and 100% of potash, according to recommended package practices CCS HAU Hisar, were applied before transplanting of the cauliflower seedlings. Field was levelled, after proper mixing of FYM and chemical fertilizers in the soil. Seedlings (40 days old) of the cauliflower (variety Snowball 16) were transplanted at spacing of 60 cm (row to row) and 45 cm (plant to plant), with a plant density of 30 plants per plot (net area 8.1 m^2 per plot), on 28th November 2021. After transplanting, first irrigation was applied same day in all the plants, sufficient

Table 1. Physical and chemical properties of the soil.

Parameters/ Properties	Soil depth (cm) 0-15 cm	15-30 cm	30-45	45-60 cm
Sand (%)	71.9	72.1	72.3	72.4
Silt (%)	18.7	19.4	18.9	19.1
Clay (%)	9.4	8.5	8.8	9.2
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Bulk density (g cm^{-3})	1.54	1.55	1.52	1.53
pH	8.1	8.3	8.6	8.7
$EC_{1:2}$ (dS m^{-1})	0.28	0.25	0.22	0.21
Available N (kg ha^{-1})	126.1	119.3	105.7	103.6
Available P (kg ha^{-1})	12.2	14.5	17.8	18.2
Available K (kg ha^{-1})	270	240	220	200
Organic carbon (%)	0.51	0.50	0.49	0.48
Basic infiltration rate		2.89 cm h^{-1}		

to ensure moisture for proper establishment of the crop. The experimental field was kept weed-free during the different stages of plant growth. Manual picking of matured curd was done during the month of February 2022.

The drippers discharge was checked randomly in different rows to maintain the uniform distribution of water through the drip irrigation system and emission uniformity of the system (Kruse 1978) was calculated using the following equation :

$$EU = \left(\frac{q_n}{q_a}\right) \times 100$$

Where,
EU = Emission uniformity of the system
q_n = Dripper discharge from drippers in the lowest 25% of discharge range (L h^{-1})
q_a = Average discharge of drippers (L h^{-1})

Irrigation was done based on 100% of crop evapotranspiration (ET_c mm). Cumulative pan evaporation was used to calculate amount of water to be applied on alternate days via drip irrigation. The volume of irrigation water to be applied per plant during an irrigation event was calculated as under (adopted from Schwab *et al.* 1993).

$$ET_C = K_C \times K_P \times CPE$$

Where,
ET_C = Crop evapotranspiration (mm)
CPE = Cumulative pan evaporation (mm)
K_C = Crop coefficient of cauliflower (Allen *et al.* 1998)
K_P = Pan coefficient (0.7)

Volume of water applied was calculated as

$$V = \frac{ET_C \times L_S \times E_S \times W_a}{\eta}$$

Where,
V = Volume of water applied (l/day/emitter)
ET_c = Crop evapotranspiration, mm
L_s = Lateral spacing, m (0.60 m)
E_s = Emitter spacing, m (0.45 m)
W_a = Wetted area factor (taken as 0.80, in case of cauliflower crop)

η = Emission uniformity of the system (0.9 as calculated)

The duration of the irrigation was calculated by :

$$\text{Irrigation time (h)} = \frac{V}{Q}$$

Where,
Q = Dripper discharge in L h^{-1}

Soil samples were collected and analyzed pe-

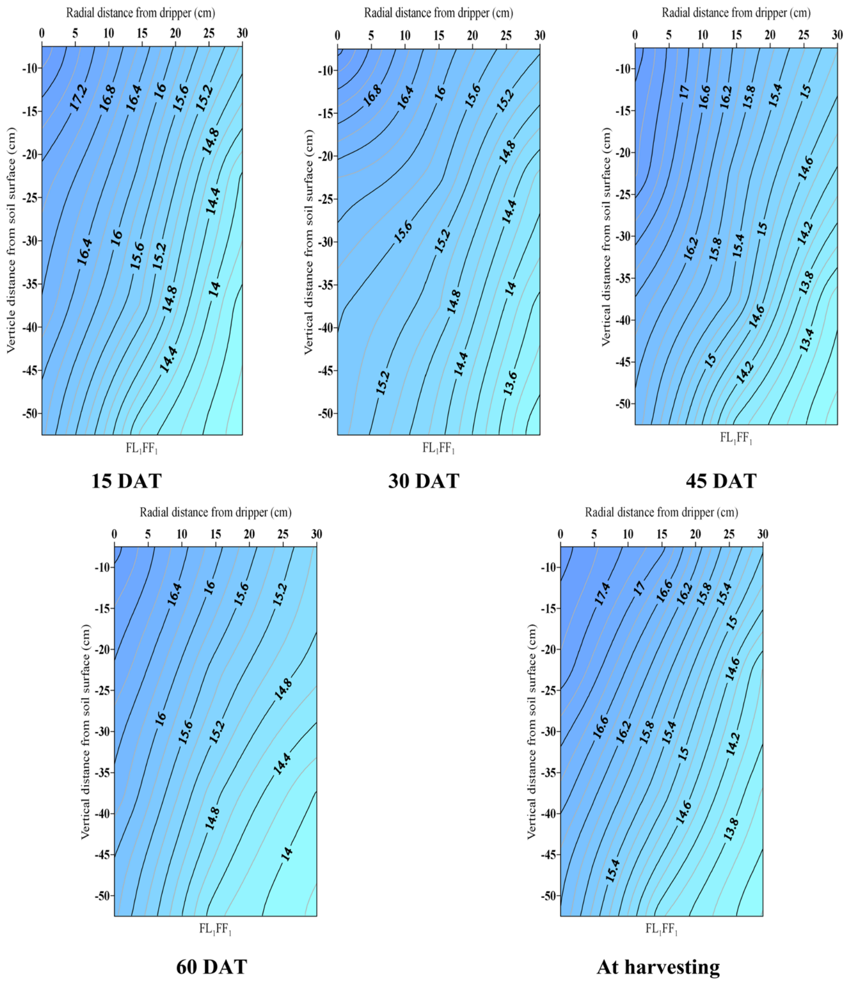

Fig. 1. Spatio-temporal distribution of soil moisture distribution (%) for the treatment N_1.

riodically (15, 30, 45, 60 DAT and at harvesting) to determine the spatial and temporal distribution of soil moisture. Soil samples were collected with the help of a tube auger, for 0-15, 15-30, 30-45 and 45-60 cm depth below the soil surface, in vertical planes located at a radial distance 0, 15 and 30 cm from dripper, perpendicular to lateral. Mass of soil samples was observed before and after drying the samples and moisture content (dry basis) was determined by equation 3.5. —

$$\text{Moisture content (\%)} = \frac{M_1 - M_2}{M_2} \times 100$$

Where,

M_1 = Mass of soil sample before drying (g)
M_2 = Mass of soil sample after drying (g)

The recommended dose of nitrogen (RDN) in cauliflower is 120 kg ha^{-1}. Nitrogen was applied under three different levels of nitrogen i. e., 75% RDN (90 kg ha^{-1}), 100% RDN (120 kg ha^{-1}) and 125% RDN (150 kg ha^{-1}). The Nitrogen fertilizer (urea) was applied in 35 equal doses with irrigation water applied at alternate day through drip irrigation system.

An inline drip irrigation system was designed and laid on the experimental plot for cauliflower crop. The control head of the system consisted of

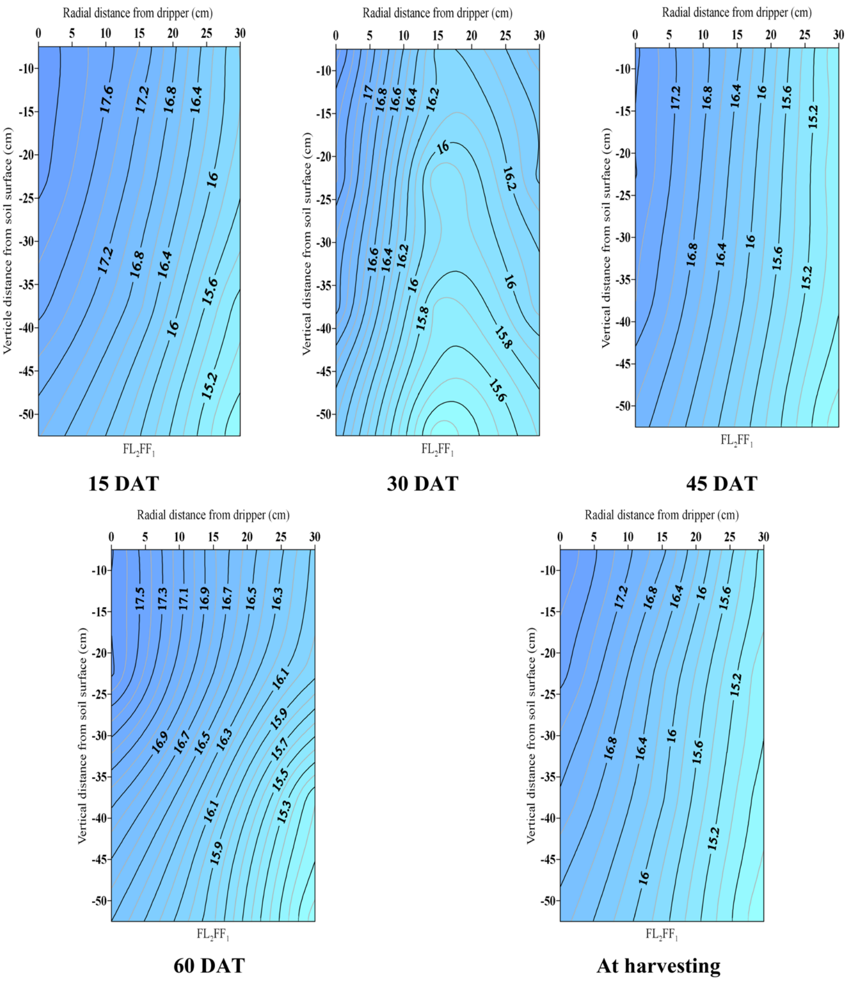

Fig. 2. Spatio-temporal distribution of soil moisture distribution (%) for the treatment N_2.

sand filter, screen filter, flow control valve, pressure gauges. The system was connected to fertigation pump for the application of fertilizers. Drip laterals of 16 mm diameter, with pressure compensating in-line drippers spaced 45 cm along the line, were used. Drip lateral lines were spaced at 60 cm interval. The rated discharge of the dripper was 2.3 L h^{-1}.

Fertigation was done through venturi starting from 28th November 2021 and continued till 18th of February 2022. The water-soluble fertilizer (Urea) was used for the fertigation. 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. The relationship between yield and irrigation water is represented by water use efficiency (WUE). WUE was calculated by comparing the fruit yield per hectare to the amount of water used in each treatment.

$$\text{WUE}\ \ (\text{kg m}^{-3})\ = \frac{\text{Total curd yield (kg ha}^{-1})}{\text{Amount of water applied (m}^{3}\ \text{ha}^{-1})}$$

The relationship between total curd yield and the quantity of nitrogen applied is represented by nitrogen use efficiency (NUE). The NUE of various treatments was estimated in relation to the amount of

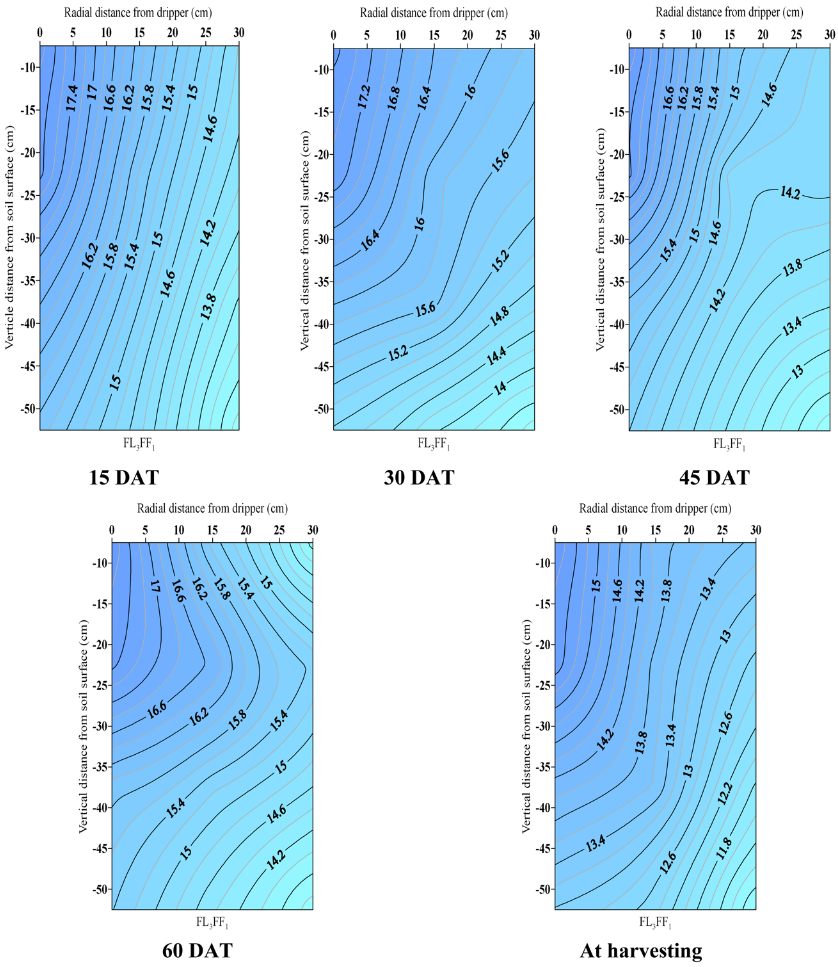

Fig. 3. Spatio-temporal distribution of soil moisture distribution (%) for the treatment N_3.

nitrogen applied per hectare and the amount of curd yield per hectare.

$$\text{NUE} = \frac{\text{Total curd yield (kg ha}^{-1}\text{)}}{\text{Amount of nitrogen applied (kg ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

During the whole cropping season, 222 liters of irrigation water (27.4 mm) was applied to each replication of every treatment. Spatial and temporal curves of moisture content are shown in Figs.1–3 (treatment wise) at 15, 30, 45, 60 days after transplanting (DAT) and at harvesting. As expected, the average moisture content decreased with the radial distance from the dripper in all the treatments. The moisture content decreased with the depth from the soil surface in all the treatments. This was due to less movement of water as we go away from the point of application either radially or deeper into the soil. The consistent soil moisture content temporally at all the distances and depths indicate that the amount of water applied in form of irrigation was optimum. Effect of nitrogen fertigation level on average moisture content was negligible. The highest curd diameter (14.1 cm) and lowest curd diameter (13.1 cm) was observed for treatments N_3 and N_1 treatments respectively. Similarly, the highest curd mass (664 g) and lowest curd mass (624 g) was observed for treatments N_3 and N_1 treatments respectively. The yield was found

Table 2. Treatment wise average curd diameter, curd mass, yield, WUE and NUE.

Treatment	Average curd diameter (cm)	Average curd mass (g)	Average yield (q ha^{-1})	Water use efficiency (kg m^{-3})	Nitrogen use efficiency (kg kg^{-1})
N_1 (75% RDN)	13.1	624	221	80.6	245.6
N_2 (100% RDN)	14.0	656	231	84.2	192.2
N_3 (125% RDN)	14.1	664	234	85.4	156.0

to be directly proportional to curd diameter as well as curd mass. Therefore, the highest yield (234 q ha^{-1}) and lowest yield (221 q ha^{-1}) was observed for treatments N_3 and N_1 treatments respectively. This might be due to increased application of fertilizers directly in the nearby areas of root zone provides better availability and uptake of nutrients for plants and it resulted in higher average yield for 125% of RDN treatments than 100% of RDN and 75% of RDN treatments. The present study results are in close agreement with the results of Sidhartha *et al.* (2021b). The estimated value of water-use-efficiency (WUE) and nitrogen-use-efficiency (NUE) is given in Table 2. Maximum WUE (85.4 kg m^{-3}) was observed in N_3 treatment and minimum WUE (80.6 kg m^{-3}) in N_1 treatment. In drip irrigation, water use efficiency in a treatment is directly proportional to yield obtained under that treatment and it resulted in higher average irrigation water use efficiency for 125% of RDN treatments than 100% of RDN and 75% of RDN treatments. The present study results are in agreement with the results of Sidhartha *et al.* (2021a). Therefore, precise water application in combination with optimum amount of nutrient supply is essential to achieve higher WUE. The maximum NUE (245.6 kg of cauliflower per kg of nitrogen) was obtained in N_1 and minimum NUE (156.0 kg of cauliflower per kg of Nitrogen) was obtained in N_3 treatment. The NUE decreased as the N fertilizer level was increased. This happened because there was a little increment in yield with the increase of N level but the amount of N level varied much in the treatments. Increased N-fertigation level supply beyond RDN did not improve the cauliflower yield and WUE much but reduced the efficiency of NUE to a great extent. Lesser NUE at higher level of nitrogen dose indicates that excessive nitrogen application might shift the balance (C:N Ratio) between vegetative and reproductive growth toward excessive vegetative development. The present study results are in agreement with the results of Katuwal *et al.* (2023).

CONCLUSION

Based on the study conducted on effect of nitrogen fertigation level, it may be concluded that fertigation level with 125% of recommended dose of nitrogen with all time nutrition (nitrogen fertigation in every irrigation) frequency may be adopted to obtain better yield of cauliflower. The increased N-fertigation level supply beyond RDN did not improve the cauliflower yield and WUE very much but reduced the NUE to a great extent. The highest NUE among these treatments was found to be under 75% RDN. Further studies are required to curtail down the N doses further to explore the possibilities of achieving yet higher NUE without a significant loss in the yield of cauliflower.

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