The Pharma Innovation Journal 2023; 12(11): 313-320

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 313-320

www.thepharmajournal.com
Received: 07-09-2023
Accepted: 16-10-2023

Manisha
Ph.D. Scholar, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India

RK Narolia
Assistant Professor, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India

Anil Kumar Yadav
Ph.D. Research Scholar, Department of Horticulture, Sikkim University, Gangtok, Sikkim, India

Ritesh Kumar
Assistant Professor, Department of Entomology, IANS, DDU, Gorakhpur University, Gorakhpur, Uttar Pradesh, India

Corresponding Author:
Anil Kumar Yadav
Ph.D. Research Scholar, Department of Horticulture, Sikkim University, Gangtok, Sikkim, India

Effect of Irrigation and nitrogen levels on growth and yield of cauliflower (*Brassica oleracea var. botrytis* L.) in arid region of Rajasthan

Manisha, RK Narolia, Anil Kumar Yadav and Ritesh Kumar

Abstract
Agriculture is the backbone of India. It is very important for the crops to meet the food requirements of the growing world population. The experiments were conducted at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, to study the effect of irrigation and nitrogen levels on the growth, and yield of cauliflower in the arid region of Rajasthan during two consecutive rabi seasons in 2021–22 and 2022–23. Experiments were laid out in a split-plot design with three replications. Irrigation levels were applied as I_1 (0.60 PE, I_2 (0.80 PE), I_3 (1.00 PE), and I_4 (1.20 PE) and Nitrogen levels were applied as N1 (control), N2 (60), N3 (90), N4 (120), and N5 (150). Results showed that different irrigation and nitrogen levels had a significant impact on the growth and yield of cauliflower. The irrigation level at 1.20 PE gave the highest growth and yield attributes, i.e., plant height (47.46 cm) and number of leaves plant^{-1} (13.27), weight of leaves (428.64 gm) and plant spread (3279 cm^2), days to curd initiation (74.40) and maturity (91.5), curd diameter (44.29 cm^2), average weight of curd (571.65 g plant^{-1}), curd yield (307.08 q ha^{-1}), biological yield (587.53 q ha^{-1}), and harvest index (52.91%), which were more than the irrigation levels of 0.60 PE and 0.80 PE, but all these attributes were statistically at par with the 1.00 PE irrigation level. Among the different levels of nitrogen, all growth parameters, *viz.*, i.e., plant height (47.16 cm) and number of leaves plant^{-1} (13.36), weight of leaves (428.64 gm) and plant spread (3279 cm^2), days to curd maturity (81.5), curd diameter (44.29 cm^2), average weight of curd (571.65 g plant^{-1}), curd yield (307.08 q ha^{-1}), and biological yield (587.53 q ha^{-1}), were maximum observed with 150 kg N ha^{-1} as compared to other levels of nitrogen, but statistically remained at par with 120 kg N ha^{-1}. However, other yield parameters like days to curd initiation (75.9), and harvest index (55.01%) were recorded higher with no nitrogen application (control).

Keywords: Cauliflower, drip irrigation, nitrogen, growth, curd yield, quality, and economics

Introduction
Cauliflower (*Brassica oleracea var. botrytis* L.) is the most popular vegetable crop among cole crops belong to the family cruciferae (Brassicaceae) (Swarup *et al.* 2006) [23]. (Gocher *et al*. 2017) [11] reported that cauliflower is being grown round the year for its white and tender curd. (Bozkurt *et al.* 2011) [4] suggested that cauliflower requires a period of cold not only for curd formation but also for flowering. Cauliflower is used as fried vegetable, dried vegetable, soup and pickles (Bashyal *et al.* 2011) [3]. The popularity and consumption of Cauliflower is increasing because of their nutritional value. It is a good source of vitamin-A, vitamin-C, riboflavin, thiamin, nicotinic acid, calcium, phosphorus, potassium, carbohydrates, protein, fat, fiber, and iron (Fageria *et al.* 2012) [7]. This vegetable when consumed confers health benefits to human as well as animals because of its richness in vitamins specially vitamin C, which is known to provide protection against certain types of cancer, help in lowering blood cholesterol, and serving as strong antioxidants (Batabyala *et al*. 2016) [2]. Drip irrigation mainly supplies water to the root zone (Xue *et al.* 2017) [27] and is the most efficient technology in providing specific quantities of water commensurate with the water consumption of the plant to achieve optimum growth and quality production (Thangaselvabai *et al.* 2009) [24]. Drip irrigation that treats water scarcity and increases crop yields is widely used in arid and semi-arid regions (Han *et al*. 2015) [14]. Nitrogen is essentially required nutrient for plant growth and fruit development. It is associated with vigorous vegetative growth and helpful in large curd compact size. Proper use of nitrogen improves the nutritional value of cauliflower with involved in physiological processes and enzymatic activities.

(Yeshiwas *et al.* 2017) [28] reported that nitrogen is a major fertilizer which is constituent of protein and protoplasm of chlorophyll and enzymes activity and required in large quantities than other nutrients (Singh *et al*. 2015) [22]. Lack of nitrogen causes stunted growth or leaves discoloration with deficiency also causes interveinal yellowing, rolling of leaves, chlorosis and necrosis and it also checks the growth, reduces the yield in cauliflower (Rani *et al*. 2015) [21]. Farmers use excessive urea as a nitrogen fertilizer to enhance flowering, curd set and increase curd size in cauliflower excessive application of nitrogen on the other hand is not only uneconomical but also induces physiological disorder and pollutes the environment (Kodithuwakku and Kirthisinghe 2009) [19].

Materials and Methods

The experimental field were arranged at the Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Raj.). The experiment was conducted in *Rabi* season for the cauliflower crop with growing period from last week of October 2021-22 to 2022-23. The present experiment was laid out in Split Plot Design (SPD) with split plot arrangement having three replications. An area of 20 × 8.4 m^2 × 3 (504 m^2) having three laterals in six rows containing 48 plants. The crop was planted during first year 2021-22 with seeds were sown on October 23rd, 2021 and during second year 2022-23 with seeds were sown on October 20th, 2022 and transplanting using a seedling of 30 days old from the nursery beds. The irrigation levels were considered as treatment comprised of four irrigation levels (0.60, 0.80, 1.00 and 1.20 PE) assigned to main plots and five nitrogen levels (control, 60, 90, 120 and 150 kg N ha^{-1}) assigned to sub plots.

Irrigation was scheduled based on study of (Huang *et al.* 2004) [15] under drip system. Pre sowing irrigation (25 mm) was applied to ensure proper germination. Irrigation was scheduled at alternate days as per treatments. The plots were irrigated by providing three laterals per plot. The lateral drip lines were laid on soil surface at 100 cm line to line distance. Dripper to dripper spacing was 30 cm with 4 lit. ha^{-1}. The irrigation water was calculated by evaporation data of daily basis. In experiment irrigation water was applying through different PE levels *viz*., 0.60, 0.80, 1.00 and 1.20. Therefore, dripper discharge rate per hour and one dripper cover area per plot were calculated for applying irrigation water and then calculated the amount of water (1mm) was applied in the field to operate drip system per hour. This calculated time was multiplied with evaporation data and converted according to different PE levels.

Nitrogen was applied at different rates *viz*., control, 60, 90, 120 and 150 kg ha^{-1} treatments in three split doses. One third dose of nitrogen was applied in the soil before transplanting. Remaining, doses of nitrogen were incorporated as top dressing in two split doses at 25 and 50 DAT.

Results and Discussion

Plant height (cm) at 45 DAT and harvest

Plant height of cauliflower plant was increased significantly by different levels of irrigation and nitrogen (Table 1) in both years and pooled basis. Highest plant height at 45 DAT and at harvest was recorded under irrigation level at 1.20 PE and which was more than irrigation levels of 0.60 PE and 0.80 PE, but statistically remained at par with 1.00 PE at 45 DAT (26.97 cm) and at harvest and nitrogen levels was highest plant height at 45 DAT (27.63 cm, 28.39 cm and 28.01 cm) and at harvest (46.38 cm, 47.93 cm and 47.16 cm) was recorded by 150 kg N ha^{-1} as compared to 60 kg N ha^{-1} and 90 kg N ha^{-1}, but remained at par with 120 kg N ha^{-1}, respectively. While, plant height of cauliflower recorded minimum in control (Without nitrogen application). However, the maximum plant height in cauliflower at the highest level of irrigation is supported by (Yu *et al.* 2006) [29] who reported that the production of fresh vegetables usually requires the application of considerable amounts of irrigation water and nitrogen fertilizer.

Table 1: Effect of irrigation and nitrogen levels on plant height (cm) of cauliflower

Treatments	Plant height (cm)					
	45 DAT			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels						
0.60 PE	21.49	21.70	21.60	34.77	35.55	35.16
0.80 PE	24.36	25.50	24.93	40.39	42.47	41.43
1.00 PE	26.62	27.32	26.97	44.52	45.76	45.14
1.20 PE	27.40	28.39	27.90	46.43	48.50	47.46
S.Em+	0.60	0.61	0.43	1.09	1.10	0.77
CD (P = 0.05)	2.09	2.10	1.32	3.78	3.80	2.39
Nitrogen levels						
Control	20.68	21.34	21.01	33.76	35.00	34.38
60 Kg N ha^{-1}	23.56	24.31	23.94	38.94	40.53	39.74
90 Kg N ha^{-1}	25.59	26.44	26.02	42.64	44.35	43.50
120 Kg N ha^{-1}	27.37	28.17	27.77	45.91	47.54	46.72
150 Kg N ha^{-1}	27.63	28.39	28.01	46.38	47.93	47.16
S.Em+	0.57	0.53	0.39	1.03	0.97	0.71
CD (P = 0.05)	1.64	1.53	1.10	2.96	2.79	1.99

Number of leaves $plant^{-1}$ at 45 DAT and harvest

The effect of irrigation and nitrogen levels on plant height was analyzed and presented in (Table 2) which shows was significant effect on increment of number of leaves $plant^{-1}$. Irrigation at 1.20 PE showed highest number of leaves $plant^{-1}$ at 45 DAT and harvest, respectively, which significantly higher than irrigation levels of 0.60 PE and 0.80 PE, but statistically at par with irrigation level 1.00 PE and nitrogen at 150 kg N ha^{-1} showed higher number of leaves $plant^{-1}$ (8.83, 8.96 and 8.90 at 45 DAT) and (13.31, 13.42 and 13.36) at harvest, but statistically remained at par with 120 kg N ha^{-1} at 45 DAT and harvest during 2021-21, 2022-23 and on pooled basis. While, number of leaves plant^{-1} of cauliflower recorded minimum in control at 45 DAT and harvest. The water and nutrient supply and maintenance of adequate moisture in the root zone from initial to harvesting stage in order to produce healthy leaves. Similar findings have been also found by (Gabhale *et al*. 2014) [10] in cauliflower.

Table 2: Effect of irrigation and nitrogen levels on number of leaves plant^{-1}of cauliflower

Treatments	Number of leaves plant^{-1}					
	45 DAT			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels						
0.60 PE	7.03	6.84	6.94	9.98	10.24	10.11
0.80 PE	7.87	7.95	7.91	11.67	11.71	11.69
1.00 PE	8.57	8.54	8.56	12.79	12.64	12.72
1.20 PE	8.77	9.03	8.90	13.18	13.35	13.27
S.Em+	0.19	0.20	0.14	0.28	0.29	0.20
CD (P = 0.05)	0.64	0.68	0.42	0.98	0.99	0.62
Nitrogen levels						
Control	6.79	6.65	6.72	9.83	9.84	9.83
60 Kg N ha^{-1}	7.63	7.64	7.63	11.17	11.28	11.23
90 Kg N ha^{-1}	8.26	8.32	8.29	12.18	12.28	12.23
120 Kg N ha^{-1}	8.81	8.89	8.85	13.06	13.11	13.08
150 Kg N ha^{-1}	8.83	8.96	8.90	13.31	13.42	13.36
S.Em+	0.18	0.17	0.13	0.28	0.25	0.19
CD (P = 0.05)	0.53	0.50	0.35	0.82	0.73	0.54

Weight of leaves (g plant^{-1}) at harvest

Data regarding the weight of leaves (g) plant^{-1}at harvest as affected by irrigation and nitrogen levels is presented in (Table 3). Statistical analysis showed that different irrigation water and nitrogen levels had significantly affected on weight of leaves of cauliflower. Irrigation at 1.20 PE showed highest weight of leaves harvest (423.10, 434.17 and 428.64 g plant^{-1}) at in 2021-22, 2022-23 and on pooled basis, respectively but statistically at par with irrigation level 1.00 PE with comparison to irrigation at 0.60 PE and 0.80 PE and nitrogen at highest weight of leaves was recorded at 150 kg N ha^{-1}, but it was statistically at par with 120 kg N ha^{-1} at harvest, respectively. While, weight of leaves (g) plant^{-1} of cauliflower recorded minimum in control at harvest. These results are supported by (Farooq *et al.* 2009) [8] who described that highest leaves weight can be obtained at higher irrigation and higher nitrogen application.

Table 3: Effect of irrigation and nitrogen levels on weight of leaves (g plant^{-1}) and plant spread (cm^2) of cauliflower

Treatments	Weight of leaves (g plant^{-1}) at harvest			Plant spread (cm^2)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels						
0.60 PE	276.39	280.14	278.27	2370	2470	2420
0.80 PE	340.27	349.59	344.93	2781	2913	2847
1.00 PE	409.88	412.68	411.28	3090	3176	3133
1.20 PE	423.10	434.17	428.64	3198	3360	3279
S.Em+	9.06	8.59	6.24	78	81	56
CD (P = 0.05)	31.33	29.71	19.23	271	280	174
Nitrogen levels						
Control	275.51	282.47	278.99	2294	2373	2334
60 Kg N ha^{-1}	346.45	353.03	349.74	2664	2799	2731
90 Kg N ha^{-1}	376.96	384.30	380.63	2942	3052	2997
120 Kg N ha^{-1}	400.45	405.73	403.09	3144	3273	3208
150 Kg N ha^{-1}	412.69	420.19	416.44	3254	3402	3328
S.Em+	8.35	8.14	5.83	79	71	53
CD (P = 0.05)	24.04	23.44	16.46	226	205	150

Plant spread (cm^2)

Data concerning plant spread (cm^2) is presented in (Table 3) was influenced significantly by levels of irrigation and nitrogen in the both years and pooled basis. Irrigation at 1.20 PE showed highest plant spread (cm^2) at harvest but statistically at par with irrigation level 1.00 PE and nitrogen at higher plant spread was recorded at 150 kg N ha^{-1}, but statistically remained at par with 120 kg N ha^{-1} at harvest. While, plant spread of cauliflower recorded minimum in control (without nitrogen content). This higher frequency of irrigation and increased availability of soil moisture under drip irrigation and nitrogen levels might have led to effective absorption and utilization of these nutrients and better proliferation of roots resulting in better plant spread area. Similar results were reported by Kage *et al.* (2001) [16] and Aladakatti *et al.* (2012) [1].

Days to curd initiation

Data regarding the days to curd initiation as affected by irrigation and nitrogen levels is presented in (Table 4.) during

2021-22, 2022-23 and pooled basis. Statistical analysis showed that different irrigation and nitrogen levels had significantly affected on the days to curd initiation of cauliflower. The maximum days to curd initiation (73.5,74.5 and 74.0 days) was reported under drip irrigation with 1.20 PE which was significantly at par with drip irrigation level 1.00 PE (72.2,72.6 and 72.4 days). However, minimum days to curd initiation (65.0, 64.3 and 64.7 days) was recorded in 0.60 PE drip irrigation. In case of nitrogen, lower days to curd initiation (66.0, 66.5 and 65.7 days) was recorded at application of 150 kg Nha^{-1} but remained statistically at par with application of 120 kg N ha^{-1}. While, higher days to curd initiation (75.9, 75.7 and 75.8 days) of cauliflower was recorded with no nitrogen application (control). Similar results were reported by (Elahi *et al.* 2015) [6] who presented that low amount of water and nitrogen application delay curd initiation.

Days to curd maturity

The presented in (Table 4) analysis of data was concluded that curd maturity was significantly affected by the levels of irrigation and nitrogen during 2021-22, 2022-23 and pooled basis. Highest days to curd maturity (90.9, 92.2 and 91.5 days) was observed at 1.20 PE drip irrigation level as compare to irrigation levels of 0.60 PE and 0.80 PE, but it was statistically at par with irrigation level 1.00 PE (89.3, 89.8 and 89.6 days). Due to the nitrogen levels of days to curd maturity was recorded lower (81.8, 88.2 and 81.5 days) at application of 150 kg N ha^{-1} but it was remained statistically at par with application of 120 kg N ha^{-1}. While, higher days to curd maturity (93.8, 93.5 and 93.7 days) of cauliflower was observed with control (no nitrogen application). Low nitrogen providing to the plant for quick maturity as compared to high nitrogen levels. The results coincide with (Tiwari and Singh 2003) [25] who described that the curd maturity was delayed by decreasing the nitrogen application.

Table 4: Effect of irrigation and nitrogen levels on days to curd initiation and curd maturity of cauliflower

Treatments	Days to curd initiation			Days to curd maturity		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels						
0.60 PE	65.0	64.3	64.7	80.7	79.8	80.2
0.80 PE	68.6	67.0	67.8	84.9	83.0	84.0
1.00 PE	72.2	72.6	72.4	89.3	89.8	89.6
1.20 PE	73.5	74.5	74.0	90.9	92.2	91.5
S.Em+	1.4	1.5	1.0	1.7	1.8	1.2
CD (P = 0.05)	4.8	5.2	3.1	5.8	6.2	3.8
Nitrogen levels						
Control	75.9	75.7	75.8	93.8	93.5	93.7
60 Kg N ha^{-1}	72.2	71.0	71.6	89.3	87.9	88.6
90 Kg N ha^{-1}	68.6	69.6	69.1	85.0	86.2	85.6
120 Kg N ha^{-1}	66.5	66.2	66.3	82.4	82.1	82.2
150 Kg N ha^{-1}	66.0	65.5	65.7	81.8	81.2	81.5
S.Em+	1.2	1.4	0.9	1.4	1.7	1.1
CD (P = 0.05)	3.4	4.1	2.6	4.1	4.9	3.1

Curd diameter (cm^2) at harvest

The data regarding to presenting in (Table 4) statistical analysis showed that irrigation and nitrogen levels had a significant effect on curd diameter (cm^2) of cauliflower during 2021-22, 2022-23 and pooled basis. Irrigation at 1.20 PE showed highest curd diameter (44.29 cm^2) at harvest compare to irrigation levels of 0.60 PE and 0.80 PE but it was at par with 1.00 PE irrigation level (42.36 cm^2). In the same way of nitrogen at maximum curd diameter (44.66 cm^2) was recorded at 150 kg N ha^{-1} but statistically remained at par with 120 kg N ha^{-1} (43.36 cm^2) at harvest. While, curd diameter (cm^2) at harvest of cauliflower recorded minimum in control (without nitrogen content). The results are similar to that of (Westerveld *et al.* 2003) [26] who reported maximum curd diameter in cauliflower can be obtained at high levels of irrigation and nitrogen. The curd diameter of cauliflower has significant effect on the market value of the crop and economic benefit.

Average weight of curd (g plant^{-1})

Data presented in (Table 5 and 6) was statistical analysis of showed that different irrigation and nitrogen levels of these two had a significant effect on average weight of curd (g plant^{-1}) during 2021-22, 2022-23 and pooled basis. The maximum average weight of curd (567.36, 576.62 and 571.65 g plant^{-1}) at harvest was found in drip irrigation at 1.20 PE, which was at par with drip irrigation at 1.00 PE (541.39, 550.84 and 546.11 g plant^{-1}) but minimum average weight of curd (336.82, 347.12 and 341.97 g plant^{-1}) was observed in drip irrigation level 0.60 PE. Similarly, at high nitrogen level of average weight of curd (601.82, 610.46 and 606.06 g plant^{-1}) in both years and in pooled basis, respectively, was recorded in 150 kg N ha^{-1} which was statistically with 120 kg N ha^{-1} (583.59, 591.47 and 587.44 g plant^{-1}) at harvest. While, it was minimum (292.43, 302.58 and 297.42 g plant^{-1}) at harvest of cauliflower in without nitrogen application (control). Increased nutrient availability in the root zone due to optimum nutrition levels leads to greater absorption and translocation of minerals, nutrients and finally increased accumulation of photosynthates by plants, might be the reasons for higher curd weight. These results are corroborated with the findings of Kumari and Mankar (2015) [18].

Table 5: Effect of irrigation and nitrogen levels on curd diameter (cm^2) at harvest (cm^2) and average weight (g plant^{-1}) of cauliflower curd

Treatments	Curd diameter (cm^2) at harvest			Average weight of curd (g plant^{-1})		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels						
0.60 PE	31.30	34.31	32.81	336.82	347.12	341.97
0.80 PE	37.24	40.02	38.63	463.47	473.69	468.58
1.00 PE	41.71	43.01	42.36	541.39	550.84	546.11
1.20 PE	43.26	45.32	44.29	567.36	576.62	571.65
S.Em+	1.13	0.93	0.73	12.45	11.55	8.49
CD (P = 0.05)	3.92	3.21	2.25	43.07	39.98	26.16
Nitrogen levels						
Control	30.14	33.73	31.94	292.43	302.58	297.42
60 Kg N ha^{-1}	35.79	38.39	37.09	406.63	418.28	412.37
90 Kg N ha^{-1}	39.51	41.61	40.56	501.83	512.53	507.10
120 Kg N ha^{-1}	42.42	44.30	43.36	583.59	591.47	587.44
150 Kg N ha^{-1}	44.02	45.29	44.66	601.82	610.46	606.06
S.Em+	1.14	0.81	0.70	10.02	10.29	7.18
CD (P = 0.05)	3.27	2.35	1.97	28.87	29.64	20.29

Interaction effect of irrigation and nitrogen levels on average curd weight (g plant^{-1}) of cauliflower

The interaction was observed that treatment combination 1.20 PE irrigation level with 150 kg N ha^{-1} (I_4N_5) reported significantly higher average curd weight (g plant^{-1}) (703.77, 710.68 and 706.89 g plant^{-1}) which was statistically at par with I_3N_5 (1.00 PE and 150 kg N ha^{-1}), I_4N_4 (1.20 PE and 120 kg N ha^{-1}) and I_3N_4 (1.00 PE and 120 kg N ha^{-1}). However, minimum average curd weight (126.32,138.11 and 132.22 g plant^{-1}) was recorded with 0.60 PE drip irrigation and without nitrogen application (control) (I_1N_1) at the same level of irrigation and nitrogen during 2021-22, 2022-23 and pooled basis. It includes production and mobilization of carbohydrates, water and nutrients uptake from the soil and several other environmental factors to which plants are exposed during the growing period. These results are in agreement with those reported by Chetan and Singh 2011 in cauliflower and Kapoor *et al*. (2014) [17].

Table 6: Interaction effect of irrigation and nitrogen levels on average curd weight (g plant^{-1}) of cauliflower

Nitrogen levels	Irrigation levels											
	2021-22				2022-23				Pooled			
	0.60 PE	0.80 PE	1.00 PE	1.20 PE	0.60 PE	0.80 PE	1.00 PE	1.20 PE	0.60 PE	0.80 PE	1.00 PE	1.20 PE
Control	126.32	227.55	389.91	425.92	138.11	237.09	399.12	436.01	132.22	232.32	394.52	430.63
60 Kg N ha^{-1}	291.47	405.26	458.49	471.30	300.86	429.62	461.37	481.29	296.16	417.44	459.93	475.95
90 Kg N ha^{-1}	356.34	524.38	556.74	569.88	365.59	533.25	571.65	579.65	360.96	528.81	564.20	574.43
120 Kg N ha^{-1}	448.52	577.59	642.32	665.91	457.56	581.90	650.96	675.46	453.04	579.75	646.64	670.35
150 Kg N ha^{-1}	461.45	582.57	659.48	703.77	473.49	586.57	671.11	710.68	467.47	584.57	665.30	706.89
			S.Em.±	CD at 5%			S.Em.±	CD at 5%			S.Em.±	CD at 5%
Irrigation at same level of nitrogen			21.82	62.87			21.73	62.68			15.40	43.51
Nitrogen at same level of irrigation			20.04	57.74			20.58	59.58			20.31	57.39

Curd yield (q ha^{-1})

Data presenting in (Table 6 and 7) showed that curd yield (q ha^{-1}) was influenced significantly by different irrigation and nitrogen levels of cauliflower in both years and on the pooled basis data. While the interactions between irrigation and nitrogen levels were also found significant. The maximum curd yield (304.55, 309.60 and 307.08 q ha^{-1}) was obtained in 1.20 PE drip irrigation, which was statistically at par with 1.00 PE drip irrigation (291.07, 296.77 and 293.92 q ha^{-1}), while least curd yield (182.96, 188.51 and 185.73 q ha^{-1}) at harvest was recorded in 0.60 PE drip irrigation level. In case of nitrogen application, the highest curd yield (322.85, 329.80 and 326.32 q ha^{-1}) was recorded at 150 kg N ha^{-1} as compared to other nitrogen treatments, but statistically remained at par with 120 kg N ha^{-1} (315.78, 319.02 and 317.40 q ha^{-1}) at harvest. While, curd yield (q ha^{-1}) at harvest of cauliflower recorded minimum (157.97, 162.58 and 160.28 q ha^{-1}) in control (without nitrogen content). The results were also supported by (Islam *et al.* 2010) who showed that maximum amount of nitrogen gives high production.

The observed that treatment combination 1.20 PE irrigation level with 150 kg N ha^{-1} (I_4N_5) reported significantly higher curd yield (376.45, 382.49 and 379.47 q ha^{-1}) but which was statistically at par with I_3N_5 (1.00 PE and 150 kg N ha^{-1}), I_4N_4 (1.20 PE and 120 kg N ha^{-1}) and I_3N_4 (1.00 PE and 120 kg N ha^{-1}). However, minimum curd yield (70.68, 73.99 and 72.34 q ha^{-1}) was observed with application of 0.60 PE drip irrigation and control (I_1N_1) at the same level of irrigation and nitrogen in 2021-22, 2022-23 and on pooled basis. The result showed that at the highest irrigation level maximum production were achieved. As nitrogen is the most essential element for plant thus high production were obtained at high level of nitrogen. The results were also supported by (Elahi *et al.* 2015) [6].

Table 7: Interaction effect of irrigation and nitrogen levels on curd yield (q ha^{-1}) of cauliflower

Nitrogen levels	Irrigation levels											
	2021-22				2022-23				Pooled			
	0.60 PE	0.80 PE	1.00 PE	1.20 PE	0.60 PE	0.80 PE	1.00 PE	1.20 PE	0.60 PE	0.80 PE	1.00 PE	1.20 PE
Control	70.68	123.72	209.28	228.22	73.99	128.91	214.28	233.16	72.34	126.31	211.78	230.69
60 Kg N ha^{-1}	158.47	220.34	246.56	252.89	163.58	233.58	248.12	257.77	161.02	226.96	247.34	255.33
90 Kg N ha^{-1}	193.74	285.10	299.98	306.49	198.77	289.92	308.09	311.25	196.25	287.51	304.03	308.87
120 Kg N ha^{-1}	243.86	314.04	346.51	358.70	248.77	312.75	351.20	363.34	246.32	313.39	348.86	361.02
150 Kg N ha^{-1}	248.05	313.90	353.00	376.45	257.44	317.10	362.16	382.49	252.74	315.50	357.58	379.47
			S.Em.±	CD at 5%			S.Em.±	CD at 5%			S.Em.±	CD at 5%
Irrigation at same level of nitrogen			11.87	34.18			11.71	33.74			8.34	23.55
Nitrogen at same level of irrigation			10.90	31.39			11.28	32.50			11.09	31.34

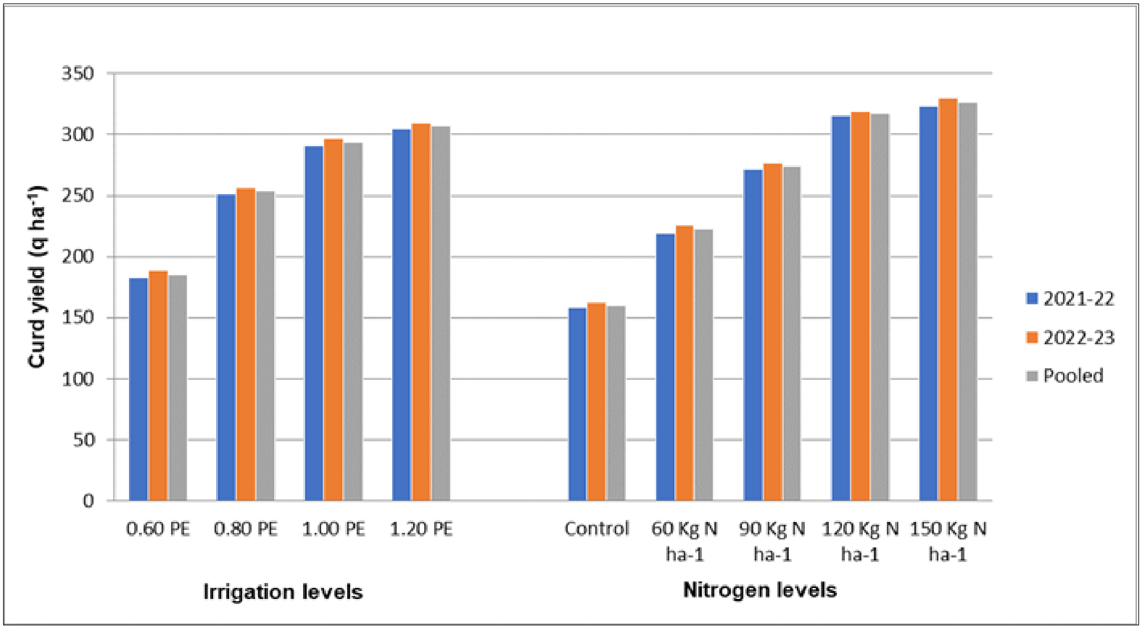

Fig 1: Effect of irrigation and nitrogen levels on curd yield (q ha^{-1}) of cauliflower

Biological yield (q ha^{-1})

Data shown in (Table 8) indicated that biological yield (q ha^{-1}) was influenced significantly by levels of irrigation and nitrogen during both years and pooled analysis. According to the data the highest biological yield of cauliflower (577.73, 597.33 and 587.53 q ha^{-1}) at harvest was reported under drip irrigation with 1.20 PE which statistically at par with drip irrigation with 1.00 PE (565.76, 561.61 and 563.68 q ha^{-1}). However, lowest biological yield (365.82, 373.44 and 369.63 q ha^{-1}) was recorded in drip irrigation level applied at 0.60 PE. Nitrogen at biological yield was maximum (651.52, 658.89 and 655.21 q ha^{-1}) when applied 150 kg N ha^{-1} than other nitrogen treatments but it was recorded at par with 120 kg N ha^{-1} (634.07, 637.82 and 635.94 q ha^{-1}) at harvest, While, cauliflower biological yield (q ha^{-1}) was obtained minimum (277.67, 292.47 and 285.07 q ha^{-1}) in control (without nitrogen application). According to the result is concluded that drip irrigation system has the ability to improve the biological yield. Thus, maximum production was achieved at the highest irrigation level. The most essential element for plant and highest yield were obtained at high level of nitrogen. These findings are supported by (Foyer *et al.* 2002) [9] who showed that high appropriate apply of irrigation and nitrogen gives high production.

Harvest index (%)

Data pertaining to harvest index (%) of cauliflower presented in (Table 8) indicated the influence of irrigation levels on harvest index (%) for the years 2021-22, 2022-23 and on pooled mean basis. Drip irrigation with 1.00 PE resulted in a significantly higher harvest index (52.92%) than 0.60 PE irrigation level but which was statistically at par with 1.20 PE (52.91%) and 0.80 PE (52.20%) irrigation levels. However, lower harvest index (50.46%) was observed in 0.60 PE drip irrigation level. While nitrogen were found the highest harvest index (55.01%) was recorded at control (without nitrogen application) compared to other nitrogen treatments. While, harvest index (%) of cauliflower was recorded minimum (49.77%) in 150 kg N ha^{-1} in pooled basis results. The results were similar with (Maurya *et al.* 1992) [20] who showed that at low levels of nitrogen application rates increases the harvest index of cauliflower.

Table 8: Effect of irrigation and nitrogen levels on curd yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of cauliflower

Treatments	Curd yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels									
0.60 PE	182.96	188.51	185.73	365.82	373.44	369.63	49.87	51.05	50.46
0.80 PE	251.42	256.45	253.94	490.11	504.24	497.17	52.20	52.19	52.20
1.00 PE	291.07	296.77	293.92	565.76	561.61	563.68	52.31	53.54	52.92
1.20 PE	304.55	309.60	307.08	577.73	597.33	587.53	53.71	52.11	52.91
S.Em+	6.77	5.95	4.50	13.84	11.88	9.12	1.18	1.80	1.07
CD (P = 0.05)	23.41	20.58	13.88	47.90	41.11	28.11	4.09	6.21	3.31
Nitrogen levels									
Control	157.97	162.58	160.28	277.67	292.47	285.07	55.01	55.01	55.01
60 Kg N ha^{-1}	219.56	225.76	222.66	412.74	422.82	417.78	53.94	53.93	53.93
90 Kg N ha^{-1}	271.33	277.01	274.17	523.27	533.77	528.52	51.94	52.15	52.05
120 Kg N ha^{-1}	315.78	319.02	317.40	634.07	637.82	635.94	49.78	49.94	49.86
150 Kg N ha^{-1}	322.85	329.80	326.32	651.52	658.89	655.21	49.44	50.09	49.77
S.Em+	5.45	5.64	3.92	8.94	10.85	7.03	1.51	1.49	1.06
CD (P = 0.05)	15.70	16.25	11.08	25.75	31.27	19.86	4.35	4.28	2.99

Conclusion

Results showed that different irrigation levels significantly affected 1.20 PE gave highest growth and yield attributes *i.e.*, plant height (cm) and number of leaves plant^{-1}, weight of leaves (gm), plant spread (cm^2), days to curd initiation, maturity, curd diameter (cm^2), average weight of curd (g plant^{-1}), curd yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (per cent) which were more than irrigation levels of 0.60 PE and 0.80 PE, but all these attributes were statistically at par with 1.00 PE irrigation level. Among the different levels of nitrogen, all growth parameters were maximum observed with 150 kg N ha^{-1} as compared to other levels of nitrogen, but statistically remained at par with 120 kg N ha^{-1}. Yield parameters like days to curd initiation and maturity and harvest index (per cent) were recorded higher with no nitrogen application (control). However, other yield attributes *i.e.,* curd diameter (cm^2) at harvest, average weight of curd, curd yield (q ha^{-1}) and biological yield (q ha^{-1}) were recorded at 150 kg N ha^{-1} but all these attributes were seen at par with 120 kg N ha^{-1}. In the data, most of the observed that treatment combination 1.20 PE irrigation level with 150 kg N ha^{-1} (I_4N_5) reported significantly higher curd yield, but which was statistically at par with I_3N_5 (1.00 PE and 150 kg N ha^{-1}), I_4N_4 (1.20 PE and 120 kg N ha^{-1}) and I_3N_4 (1.00 PE and 120 kg N ha^{-1}). However, minimum curd yield was observed with application of 0.60 PE drip irrigation and control (I_1N_1) at the same level of irrigation and nitrogen.

Reference

1. Aladakatti YR, Palled YB, Chetti MB, Halikatti SI, Alagundagi SC, Patil PL, *et al*. Effect of nitrogen, phosphorus and potassium levels on growth and yield of stevia (*Stevia rebaudiana Bertoni*). Karnataka J. Agric. Sci. 2012 Jun 25;25(1):25-9.
2. Batabyal K, Mandal B, Sarkar D, Murmu S, Tamang A, Das I, *et al*. Comprehensive assessment of nutrient management technologies for cauliflower production under subtropical conditions. European Journal of Agronomy. 2016 Sep 1;79:1-3.
3. Bashyal LN. Response of cauliflower to nitrogen fixing biofertilizer and graded levels of nitrogen. Journal of Agriculture and Environment. 2011;12:41-50.
4. Bozkurt S, Uygur V, Agca N, Yalcin M. Yield responses of cauliflower (*Brassica oleracea* L. *var. Botrytis*) to different water and nitrogen levels in a Mediterranean coastal area. Acta Agriculturae Scandinavica Section B-Soil and Plant Science. 2011 Mar 1;61(2):183-94.
5. Singla C, Singh KG. Crop water requirements and fertigation options for early drip irrigated cauliflower (*Brassica oleracea var. botrys* Linn.) grown in a greenhouse. Progressive Horticulture. 2011;43(1):99-101.
6. Elahi E, Wali A, Nasrullah GA, Ahmed S, Huma Z, Ahmed N. 06. Response of cauliflower (*Brassica oleracea var. Botrytis* L.) cultivars to Phosphorus levels. Pure and Applied Biology (PAB). 2021 Oct 18;4(2):187-94.
7. Fageria MS, Choudhary BR, Dhaka RS. Vegetable Crops Production Technology, volume-II. Kalyani Publication, Noida (UP); c2012.
8. Farooq M, Wahid A, Kobayashi NS, Fujita DB, Basra SM. Plant drought stress: effects, mechanisms and management. Sustainable agriculture. 2009:153-88.
9. Foyer CH, Vanacker H, Gomez LD, Harbinson J. Regulation of photosynthesis and antioxidant metabolism in maize leaves at optimal and chilling temperatures. Plant Physiology and Biochemistry. 2002 Jun 1;40(6-8):659-68.
10. Gabhale LK, Bhopale SR, Chaudhari GV. Effect of varieties and planting dates on horticultural quality of cauliflower. BIOINFOLET-A Quarterly Journal of Life Sciences. 2014;11(3a):814-6.
11. Gocher P, Soni AK, Mahawar AK, Singh SP, Sharma D, Singh B. Effect of NPK and sulphur on growth attributes and chlorophyll content of cauliflower (*Brassica oleracea var. botrytis* L.) variety Pusa Synthetic. Chemical Science Review and Letters. 2017;6(23):1544-8.
12. Islam MH, Shaheb MR, Rahman S, Ahmed B, Islam AT, Sarker PC. Curd yield and profitability of broccoli as affected by phosphorus and potassium. International Journal of Sustainable Crop Production. 2010 May;5(2):1-7.
13. Easmin D, Islam MJ, Begum K. Effect of different levels of nitrogen and mulching on the growth of Chinese cabbage (*Brassica campestris var. Pekinensis*). Progressive Agriculture. 2013 Nov 4;20(1-2):27-33.
14. Han M, Zhao C, Feng G, Yan Y, Sheng Y. Evaluating the effects of mulch and irrigation amount on soil water distribution and root zone water balance using HYDRUS-2D. Water. 2015 May 29;7(6):2622-40.
15. Huang Y, Chen L, Fu B, Huang Z, Gong J. The wheat yields and water-use efficiency in the Loess Plateau: straw mulch and irrigation effects. Agricultural water management. 2005 Apr 2;72(3):209-22.
16. Kage H, Stützel H, Alt C. Predicting dry matter production of cauliflower (*Brassica oleracea Var. Botrytis* L.) under unstressed conditions: Part II. Comparison of light use efficiency and photosynthesis-respiration based modules. Scientia horticulturae. 2001 Feb 19;87(3):171-90.
17. Kapoor R, Sandal SK, Sharma SK, Kumar A, Saroch K. Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea var. botrytis*) in wet temperate zone of Himachal Pradesh. Indian Journal of Soil Conservation. 2014;42(1):19.
18. Kumari C, Mankar A, Karuna K, Solankey SS, Singh VK. Effect of different levels of nitrogen and microbial inoculants on yield and quality of cabbage (*Brassica oleracea var. capitata*) cv Pride of India. Indian J. Agric. Sci. 2015 Apr 1;85:515-8.
19. Kodithuwakku DP, Kirthisinghe JP. The effect of different rates of Nitrogen fertilizer application on the growth yield and postharvest life of Cauliflower.Tropical Agricultural Research. 2009;21(1):110-114.
20. Maurya AN, Chaurasia SN, Reddy YR. Effect of nitrogen and molybdenum levels on growth, yield and quality of cauliflower (*Brassica oleracea var. Botrytis*) cv. Snowball-16. Haryana Journal of Horticultural Sciences. 1992;21:232-.
21. Rani PL, Balaswamy K, Rao AR, Masthan SC. Evaluation of integrated nutrient management practices on growth, yield and economics of green chilli CV Pusa Jwala (*Capsicum annuum* L.). International Journal of Bio-resource and Stress Management. 2015;6(1):76-80.
22. Singh MK, Chand T, Kumar M, Singh KV, Lodhi SK,

Singh VP, *et al*. Response of different doses of NPK and boron on growth and yield of broccoli (*Brassica oleracea var. italica*). International Journal of Bio-resource and Stress Management. 2015;6(Feb, 1):108-12.
23. Swarup V. Vegetable Science and Technology in India. Journal of Indian Society of Vegetable Science. 2006;14(3):656.
24. Thangaselvabai T, Suresh S, Joshua JP, Sudha KR. Banana nutrition-A review. Agricultural Reviews. 2009;30(1):24-31.
25. Tiwari KN, Singh A, Mal PK. Effect of drip irrigation on yield of cabbage (*Brassica oleracea var. capitata*) under mulch and non-mulch conditions. Agricultural water management. 2003 Jan 1;58(1):19-28.
26. Westerveld SM, Mc Donald MR, Scott Dupree CD, Mc Keown AW. Optimum nitrogen fertilization of cauliflower. Acta Horticulture. 2003;6(27):211-215.
27. Xue DX, Zhang HJ, Ba YC, Zhang M, Wang SJ. Effects of regulated deficit irrigation on soil environment and yield of potato under drip irrigation. Acta Agric. Boreali-Sinica. 2017;3(32):229-38.
28. Yeshiwas Y. Effect of different rate of nitrogen fertilizer on the growth and yield of cabbage (*Brassica oleracea*) at Debre Markos, North West Ethiopia. African Journal of Plant Science. 2017 Jul 31;11(7):276-81.
29. Yu HM, Li ZZ, Gong YS, Mack U, Feger KH, Stahr K. Water drainage and nitrate leaching under traditional and improved management of vegetable-cropping systems in the North China Plain. Journal of Plant Nutrition and Soil Science. 2006 Feb;169(1):47-51.