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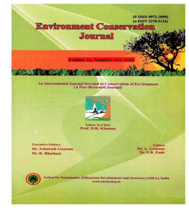

Response of irrigation scheduling and nitrogen levels on growth and yield contributing parameters of radish (*Raphanus sativus* L.) under mid hills of Himachal Pradesh

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ABSTRACT

An on-farm study of irrigation scheduling and nitrogen level on radish was conducted near Solan, Himachal Pradesh, India. It using a randomized block design (factorial) with 4 irrigation schedules i.e. I_0, 4 cm irrigation at IW/CPE ratio (I_1: 0.8), (I_2:1.0), (I_3:1.2) and three N levels i.e. N_0, (N_1:75 per cent of RD) and (N_2:100 percent of RD). Results revealed that treatment combination N_2I_3 was recorded with maximum number of leaves (27.3 and 25.0), leaf length (32.53 cm and 29.44 cm), root length (22.21 cm and 32.91 cm), root diameter (4.58 cm and 5.28 cm), net root weight (156.2 g and 209.1 g), gross root weight (204.6 g and 341.3 g) and yield (309.0 quintals/ha and 288.1 quintals/ha during 2016-17 and 2017-18, respectively over the N_0I_0. The highest B:C ratio (3.61:1) was worked out under N_2I_3 which was rated as the most profitable combination followed by N_2I_2 (3.39:1). It can be concluded that among different irrigation schedules,I_3 and I_2 schedules were found to be equally good for maintaining optimum soil moisture content as compared to I_1 and I_0. Among different N levels, N_2 was found to be best which might influence the growth and yield of radish (*Raphanus sativus* L.).

Introduction

Agriculture is the primary source of income for the people of Himachal Pradesh and plays a significant role in the state's economy. Himachal Pradesh is the only state in the country with a rural population of 89.96 percent. Although Himachal Pradesh is blessed with natural beauty, perennial rivers, and snow-capped mountains, it also suffers from water scarcity and deteriorating water quality as a result of human intervention and development activities, which is likely to worsen as the population grows and people's lifestyles change. It is the State's responsibility to put the restricted and scarce water resources to the most cost-effective, efficient, and long-term use possible in order to promote their optimal use for irrigation and other purposes in accordance with the priorities. The role of irrigation in ensuring food security is vital as about 40 per cent of world food is produced by irrigated agriculture (FAO, 2002). As the world's population grows, so does the demand for food and fibre, resulting in the use of irrigation to keep plants growing (Delfine *et al.,* 2000). Irrigation is used in all places of the world where rainfall does not provide enough ground moisture (Bhuiya *et al.,* 2003). The amount and frequency of irrigation determined by irrigation scheduling is governed by many complex factors, but climate plays a major role. Therefore, it is necessary to develop irrigation

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scheduling techniques under prevailing climatic condition and due to lack of proper irrigation scheduling techniques, the average yield of these vegetable crops is low which might be due to excess or deficit soil moisture regimes(Imitiyaz *et al.,,* 2000). Various studies have been carried out earlier on irrigation scheduling techniques under a wide range of irrigation system and management, soil, crop and climatic conditions. Water stress is one of the major limitations to the agricultural productivity worldwide, particularly in warm, arid, and semi-arid parts of the world.

Radish is the root crop belongs to family Brassicaceae. Being a shallow rooted crop, radish needs frequent and light irrigations for better growth, development and higher yield of better quality. However, farmers irrigate radish through flooding observing the dryness of soil. Improper irrigation practices not only cause wastage of expensive and scarce water resource but also decrease crop yield, quality, water use efficiency and economic returns. As water for irrigation is a scare resource, its optimization is fundamental to water resource use. It permits better utilization of all other production factors and thus leads to increased yield per unit area per unit time. Inadequate water supply at improper time results in moisture stress reduced nutrient uptake and lower water use efficiency (Olezyk *et al.,* 2000). One of the most important aspects of agro-techniques for optimising carrot yield is irrigation schedule. Water is the only factor that has a direct impact on vegetable yield (Siddiqui, 1995).Water stress reduces crop canopy and biomass growth, resulting in a drop in production. Water application scheduling is critical to make the most efficient use of drip irrigation system, since excessive irrigation reduces yield and insufficient irrigation causes water stress and lowers production (Kashyap and panda, 2003; Wang *et al.,* 2006).Scarcity of irrigation water is an acute problem for successful crop production anywhere in the world (Chowdhury *et al.,* 1999). As a result, efficient use of scarce irrigation water is critical for high-quality carrot production (Islam *et al.,* 2015). The key component that determines the nitrate concentration in vegetables is nitrogen fertiliser, which has been identified as one of the most important factors impacting yield and chemical composition of vegetables. Excess nitrogenous fertiliser is commonly applied to crops as a suitable insurance against production losses and their financial effects (Huang, 2002). Nitrogen is very essential for leafy and root vegetable production. Its application upholds the overall growth, yield and quality of radish (Brintha and Seran, 2009).

Material and Methods

Site description

The field experiment was carried out during the Rabi seasons of 2016-2017 and 2017-2018 at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, in the experimental farm of Soil Science and Water Management (HP).It is situated at 30° 52'N latitude and 77° 11' E longitude, with an elevation of 1175 m above mean sea level and a 7-8% average slope. The study region is located in Himachal Pradesh's sub-temperate, sub-humid agro-climatic zone (zone-2). The area's average annual rainfall is around 1100 mm, with roughly 75% of it falling during the monsoon season (mid June-mid September).During the growing seasons of Radish, the mean minimum and maximum temperatures recorded ranged from 3 to 14°C. Winter rains are scarce, falling primarily in January and February. Rainfall and pan evaporation data for the research region were obtained from the meteorological observatory of the University's Department of Environmental Science for both years of the experiment. According to the USDA's Soil Taxonomy, the soil in the area belongs to the TypicEutrochrept sub-group. The texture of the soil is sandy loam, and its reaction is neutral (Table 1).

Table1: Salient physical properties of experimental soil

Properties	Depth (cm)	
	0-15	15-30
Sand (%)	58.7	59.5
Silt (%)	27.2	28.5
Clay (%)	14.1	12.0
Textural class	Sandy Loam	Sandy Loam
Bulk density (g cm^{-3})	1.29	1.31
Moisture retention at 0.33 bar (w,%)	23.9	21.0
Moisture retention at 15 bar (w,%)	7.2	6.8
Available water (w,%)	16.7	14.2

Trial establishment and observation

The experiment was laid out in randomized block factorial design consisting of combinations of four irrigation treatments included I_oN_o irrigation (control), I_1, I_2, I_3 (4 cm irrigation at 0.6, 0.8, 1.2 IW/CPE ratio respectively) as the main factor and three nitrogen rates were applied N_o no nitrogen (control), N_1, N_2 (75, 100 per cent of recommended dose of N respectively), as the sub main factor applied through surface irrigation. Pusa Himani variety of radish was sown at spacing 30 cm × 10 cm on 3m ×2 m beds. Farm yard manure and recommended levels of P_2O_5 and K_2O nutrient were added in each plot equally as per recommended dose (SSP300 kg/ha and MOP 60 kg/ha respectively) for radish. Nitrogen in the form of urea was applied as per the experiment schedule. After sowing, the light irrigation was given at alternate days till the proper germination of seeds. Thereafter, the crop was irrigated with 4 cm common irrigation. Then as per schedules of irrigation, subsequent irrigations were applied. In schedules I_1, I_2, and I_3 4 cm irrigation was applied at irrigation water (IW) and the cumulative pan evaporation (CPE) ratios were 0.8, 1.0 and 1.2 respectively. All the other recommended package of practices of Dr Yashwant Singh Parmar University of Horticulture and Forestry was followed for successful raising of Radish.

Analysis of growth and yield parameters

In each treatment, fifteen plants were chosen at random to study the plant parameter. From the base of the petiole to the highest point of the leaves, leaf length was measured in centimetres using a metre scale, while root length was measured from crown to distal end. Root diameter was recorded just below the crown with the help of digital vernier calliper. Gross root weight was recorded by weighing the roots along with leaves while for calculating net root weight; roots were properly cleaned to remove the soil sticking to them and weighed individually.

Dry matter content (%)

The roots harvested in each treatment were thoroughly cleaned and one kilogram of fresh roots was drawn from each treatment. Those roots were washed in running tap water and then oven dried at 65±5°C till a constant weight. The dry matter was expressed in percentage using following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight (g)}}{\text{Fresh weight (g)}} \times 100$$

Statistical analysis

To analyse the influence of treatments on yield and yield attributing features of radish, all data were subjected to analysis of variance (ANOVA) suited to the experimental design. The data recorded was analyzed by using MS EXCEL, SPSS 11.5 Software and the mean values of data were subjected to ANOVA as described by Panse and Sukhatme, 2000) for RBD (factorial). Comparison of treatment means was carried out using the critical difference (CD) at 5 % probability level.

Results and Discussion

Growth parameters

The influence of irrigation schedules and N levels on the number of leaves was significant during both years of the study, according to the data in (Table 2).During both years of study, highest number of leaves (25.2 and 23.4) were recorded with N_2 while minimum (15.5 and 19.8) under control (N_0). Under irrigation levels, significantly higher (21.0 and 23.3) number of leaves were recorded under I_3 schedule and minimum (18.9 and 20.7) under control (I_0) during 2017 and 2018, respectively. Under interaction significantly higher (27.3 and 25.0) numbers of leaves were recorded under N_2I_3 and lower (14.6 and 17.8) under N_0I_0. Irrigation schedules I_3, I_2 and I_1 significantly increased the number of leaves by 10.4, 9.0 and 4.5 per cent over I_0. Among N levels, the increase was 38.1 per cent in N_2 and 21.0 per cent over N_0. The results were found to be in line with those of Acar *et al.* (2008) and Amiri *et al.* (2012) who found that the increasing of irrigation frequency caused an increase in number of leaves in eggplant and lettuce, respectively. The more number of leaves in plant grown under higher N level might have been associated with the application of N in adequate quantity that positively improved the vegetative growth of radish plant. Jilani *et al.* (2010) in radish and Wahocho *et al.* (2016) in turnip found the positive and significant effect of N on number of leaves.Irrigation schedules, N levels, and their interaction had a significant effect on leaf length during both years of the study, according to the data in Table 2.

Table 2: Effect of irrigation schedules and N levels on growth parameters of radish.

Nitrogen levels	Irrigation Schedule									
	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean
	2016-2017					2017-2018				
	Number of leaves per plant									
No Nitrogen (Control)	14.6	14.9	15.6	16.9	**15.5**	17.8	19.4	20.4	21.3	**19.8**
75 % dose of Nitrogen	18.9	20.9	21.3	18.9	**20.0**	21.8	22.4	22.7	23.4	**22.6**
100 % RDN	23.3	24.5	25.6	27.3	**25.2**	22.4	22.3	23.8	25.0	**23.4**
Mean	**18.9**	**20.1**	**20.8**	**21.0**		**20.7**	**21.4**	**22.3**	**23.3**	
CD (P=0.05) of N			1.7					0.9		
CD (P=0.05) of I			1.9					1.0		
CD (P=0.05) N×I			3.3					1.9		
	Leaf Length (cm)									
No Nitrogen (Control)	21.03	23.31	24.57	27.13	**24.01**	19.89	21.27	22.11	22.50	**21.44**
75 % dose of Nitrogen	27.80	28.53	28.77	29.97	**28.77**	23.08	23.22	24.32	24.72	**23.83**
100 % RDN	31.00	29.53	31.73	32.53	**31.20**	25.33	26.33	26.44	29.44	**26.89**
Mean	**26.61**	**27.12**	**28.36**	**28.88**		**22.77**	**23.61**	**24.29**	**25.55**	
CD (P=0.05) of N			1.17					1.20		
CD (P=0.05) of I			1.36					1.38		
CD (P=0.05) N×I			2.33					2.38		
	Root length (cm)									
No Nitrogen (Control)	19.52	19.58	19.86	19.78	**19.69**	21.68	23.60	22.58	22.47	**22.58**
75 % dose of Nitrogen	20.03	19.75	19.51	21.03	**20.08**	21.55	24.57	28.67	28.77	**25.89**
100 % RDN	21.29	21.43	21.82	22.21	**21.69**	28.74	27.44	28.47	32.91	**29.81**
Mean	**20.28**	**20.25**	**20.40**	**21.01**		**23.99**	**25.20**	**26.57**	**28.03**	
CD (P=0.05) of N			0.89					4.50		
CD (P=0.05) of I			1.02					5.16		
CD (P=0.05) N×I			1.7					8.94		
	Root diameter (cm)									
No Nitrogen (Control)	3.22	3.25	3.55	3.72	**3.43**	3.48	3.68	3.88	4.05	**3.78**
75 % dose of Nitrogen	3.88	3.75	3.88	3.92	**3.87**	4.08	4.25	4.35	4.75	**4.36**
100 % RDN	4.08	4.22	4.32	4.58	**4.30**	4.07	4.95	4.95	5.28	**5.00**
Mean	**3.73**	**3.75**	**3.92**	**4.07**		**4.13**	**4.29**	**4.39**	**4.69**	
CD (P=0.05) of N			0.15					0.22		
CD (P=0.05) of I			0.18					0.25		
CD (P=0.05) N×I			0.3					0.44		

Table 3: Effect of irrigation schedules and N levels on yield parameters of radish.

Nitrogen levels	Irrigation Schedule									
	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean
	2016-2017					2017-2018				
	Net root weight (g)									
No Nitrogen (Control)	106.5	117.5	125.8	138.8	**122.2**	114.2	121.6	123.9	125.8	**121.4**
75 % dose of Nitrogen	134.2	132.5	150.8	139.5	**139.3**	135.9	140.9	152.6	155.0	**146.1**
100 % RDN	153.8	149.2	142.5	156.2	**150.4**	163.1	174.1	180.6	209.1	**181.8**
Mean	**131.5**	**133.2**	**139.7**	**144.8**		**137.7**	**145.6**	**152.4**	**163.3**	
CD (P=0.05) of N			14.5					8.4		
CD (P=0.05) of I			16.6					9.7		
CD (P=0.05) N×I			28.80					16.80		
	Gross root weight (g)									
No Nitrogen (Control)	154.3	157.9	172.6	172.6	**164.3**	213.3	229.3	249.1	264.3	**239.0**
75 % dose of Nitrogen	189.3	186.9	174.3	171.9	**180.6**	269.4	280.0	291.8	311.7	**288.2**
100 % RDN	163.6	212.3	192.6	204.6	**193.3**	321.8	327.3	341.3	357.7	**337.0**
Mean	**169.0**	**185.7**	**179.8**	**183.0**		**268.2**	**278.9**	**294.1**	**311.2**	
CD (P=0.05) of N			18.2					4.7		
CD (P=0.05) of I			20.9					5.4		
CD (P=0.05) N×I			36.2					9.3		
	Yield (q ha^{-1})									
No Nitrogen (Control)	174.0	206.7	222.7	226.0	**207.4**	165.0	180.7	202.7	210.4	**189.7**
75 % dose of Nitrogen	228.7	236.0	243.0	252.0	**239.9**	223.2	232.0	247.6	255.4	**239.6**
100 % RDN	251.0	265.6	288.3	309.0	**278.5**	259.5	265.0	273.9	288.1	**271.6**
Mean	**217.9**	**236.1**	**251.3**	**262.3**		**215.9**	**225.9**	**241.4**	**251.3**	
CD (P=0.05) of N			9.0					24.7		
CD (P=0.05) of I			10.4					28.6		
CD (P=0.05) N×I			18.0					49.4		
	Dry matter content (%)									
No Nitrogen (Control)	5.60	5.50	5.40	6.10	**5.65**	7.83	7.43	7.27	6.50	**7.26**
75 % dose of Nitrogen	6.82	7.53	7.93	8.43	**7.68**	5.93	7.83	7.80	8.40	**7.49**
100 % RDN	8.23	8.07	9.47	10.50	**9.06**	7.80	9.43	9.57	10.80	**9.40**
Mean	**6.88**	**7.03**	**7.60**	**8.34**		**7.19**	**8.23**	**8.21**	**8.57**	
CD (P=0.05) of N			0.72					0.74		
CD (P=0.05) of I			0.83					0.85		
CD (P=0.05) N×I			NS					1.47		

Table 4: Cost economics of different treatment combination in radish.

Treatments	Fixed cost (Rs)	Variable Cost (Rs)	Total Cost (Rs ha^{-1})	Yield (q ha^{-1})	Gross income (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
N_0I_0	21200	**102674**	123874	169.5	339000	215126	1.74
N_0I_1	21200	**105174**	126374	193.7	387400	261026	2.07
N_0I_2	21200	**106424**	127624	212.7	425400	297776	2.33
N_0I_3	21200	**107674**	128874	218.2	436400	307526	2.39
N_1I_0	21200	**103108**	124308	226	452000	327692	2.64
N_1I_1	21200	**105608**	126808	234	468000	341192	2.69
N_1I_2	21200	**106858**	128058	245.3	490600	362542	2.83
N_1I_3	21200	**108113**	129313	253.7	507400	378087	2.92
N_2I_0	21200	**103252**	124452	255.3	510600	386148	3.10
N_2I_1	21200	**105752**	126952	265.3	530600	403648	3.18
N_2I_2	21200	**107002**	128202	281.1	562200	433998	3.39
N_2I_3	21200	**108252**	129452	298.6	597200	467748	3.61

Average leaf length increased with increase in irrigation and N levels. During both years of study, among N levels, significantly higher (31.20 and 26.89 cm) and lower (24.01 and 21.44 cm) leaf length was recorded under N_2 and N_0 levels respectively. Under irrigation levels, maximum leaf length (29.88 and 25.55 cm) was recorded under I_3 schedule and minimum (26.61 and 22.77 cm) under control which was statistically at par with I_1 (27.12 and 23.61 cm) during 2017 and 2018, respectively. During both years of research, interaction had a significant impact on leaf length. During 2016-17, maximum leaf length (32.53 cm) was recorded under N_2I_3 which was statistically at par with N_2I_2 (31.73 cm) while during 2017-18, maximum (29.44 cm) leaf length was recorded under N_2I_3. Minimum (21.03 and 19.89 cm) leaf length was recorded under N_0I_0 during both the years, respectively. Leaf length in N_2 and N_1 being 27.8 and 15.7 percent higher over N_0,it is possible that this is related to beneficial effects of nitrogen on cell division, cell expansion, and protein synthesis. Irrigation schedule I_3, I_2 and I_1 significantly increased the leaf length by 10.3, 6.7 and 2.8 percent over I_0. It could be because of optimal soil moisture content throughout the growing season, which is important for transpiration, stomatal opening, and leaf growth and expansion. Jilani *et al.* (2010) in radish, Wahocho *et al.* (2016) in turnip, and Bhatti *et al.* (2019) in onion reported similar results. During both the years of the study, the data in Table-2 revealed a significant effect of irrigation schedules, N levels, and their interaction on radish root length. In 2016-17 and 2017-18, the I_3 irrigation schedule had the maximum root length (21.01 and 28.03 cm), while the lowest (20.28 and 23.99 cm) was under control. Among N levels maximum root length (21.69 and 29.81 cm) was observed under N_2 level and minimum (19.69 and 22.58 cm) under N_0 (control) which was statistically at par with N_1 (20.08 and 25.89 cm) during both the years of research. In case of interactions during2016-17, significantly higher (22.21 cm) root length was observed under N_2I_3 which was statistically at par with N_2I_2 (21.82 cm) and N_2I_1 (21.43 cm) while during 2017-18 maximum root length (32.9 cm) was recorded under N_2I_3.Irrigation schedule I_3, I_2 and I_1 significantly increase root length by 10.0, 6.1 and 2.7 percent over I_0. Among N levels, the increase was 21.8 in N_2 and 8.9 percent in N_1 over N_0. Environmental and genetic factor strongly effect root length, so plant with more number of leaves have more root length (Tripathi *et al.* 2017). The findings of Alam *et al.* (2010) in carrot, Jilani *et al.* (2010) in radish, and Baloch *et al.,* (2014) in radish support the findings. The observations recorded indicated the significant effect of irrigation schedules, N levels and their interaction on root diameter of radish and trend was almost similar during both the years of study (Table-2). During both the years of study, irrigation schedule I_3 was recorded with highest root diameter (4.07 and 4.69 cm) followed by I_2 (3.92 and 4.39 cm) and minimum (3.73 and 4.13 cm) was under control (I_0). Under N levels, significantly highest (4.30 and 5.00 cm) and lowest (3.43and 3.78 cm) root diameter was recorded with N_2 and N_0 level, respectively. In case of interactions, N_2I_3 was recorded with maximum (4.58 and 5.28 cm) root diameter while N_0I_0 was recorded with lowest (3.22 and 3.48 cm) during both the years of study. While among N levels, significantly higher root diameter (4.65 cm) was recorded under N_2 which was 28.8 percent higher than N_0 (3.61 cm) followed by N_1 (4.12 cm) which was 14.1 percent higher over N_0. In case of interactions, maximum root diameter (4.93 cm) was recorded with N_2I_3 while lowest (3.35 cm) under N_0I_0 which was statistically at par with N_0I_1 (3.47 cm). Maximum root diameter in plot receiving more N had a higher number of leaves. It could be attributed to increased photosynthetic activity, which resulted in increased food production and root storage (Ali *et al.,* 2006). The findings are consistent with those of Sadia *et al.* (2013) in turnip, Alam *et al.* (2010) in carrot, and Moniruzzaman *et al.* (2013) in turnip.

Yield parameters

The influence of irrigation schedules, N levels, and their interaction on net root weight was substantial during both years of study, according to data in (Table-3).Under irrigation schedules, highest (144.8 and 163.3 g) net root weight was recorded under I_4 followed by I_2 (139.7 and 152.4 g) and lowest (131.5 and 137.7 g) under I_0 during both the years of study. Among N levels, significantly higher (150.4 and 181.8 g) net root weight was recorded with N_3 and lower (122.2 and 121.4 g) under N_0 (control). In case of interaction effect during both the years of study, significantly higher (156.2 and 209.1 g) and lower (106.5 and 114.2 g) net root weight was recorded under N_2I_3 and N_0I_0. Irrigation schedules I_3, I_2 and I_1 recorded significantly higher net root weight and increase was to the tune of 14.5, 8.5 and 3.6 per cent, respectively over the control (I_0). Among N levels, the increase was 36.4 percent in N_2 and 17.2 percent in N_1 over the control (N_0). The influence of irrigation schedule, N levels, and their interaction on gross 'root weight of radish was significant throughout both years of study (Table-3). Under irrigation schedules, significantly higher (185.7 g) gross root weight was recorded under I_1 followed by I_3 (183.0 g) and lower (169.0 g) under control (I_0). Among N levels, N_2 level was recorded with highest (193.3 g) gross root weight which was statistically at par with N_1 (180.6 g) and lowest (164.3 g) under control (N_0) during 2016-17. During 2017-18, highest (311.2 g) gross root weight was recorded with I_3 schedule and lowest (268.2 g) under control (I_0). Under N levels, significantly higher (337.0 g) and lower (239.0 g) gross root weight was recorded under N_2 and N_0 levels, respectively. The significant effect of interaction (N×I) was found throughout both the years of study and significantly higher (204.6 and 357.7 g) gross root weight was recorded under N_2I_3 and lower (154.3 and 213.3 g) under control (N_0I_0) during 2016-17 and 2017-18, respectively. The higher net and gross root weight at irrigation schedule I_3 with 100 percent RDN might be due to the optimum soil moisture content (Table-3), because of the split application; N has perfect solubility, mobilisation, and availability at regular intervals in the required quantity. The reports of Goudra and Rokhade, (2001) on cabbage, Jilani *et al.,* (2010) on radish, Kumari, (2013) on turnip and Sadia *et al.,* (2013) on cauliflower corroborate these results.

During both years of the study, the influence of irrigation schedules, N levels, and their interaction on yield was considerable, according to the results showed in Table-3. Under irrigation schedules, significantly higher (262.3 and 251.3 quintal/ ha) yield was noticed under I_3 schedule which was statistically at par with I_2 (251.3 and 241.4 quintal/ ha) and lower (217.9 and 215.9 quintal/ ha) under control (I_0) during 2016-17 and 2017-18, respectively. Among N levels, significantly higher (278.5 quintal/ ha in 2016-17 and 271.6 quintal/ ha in 2017-18) and lower (207.4 quintal/ ha in 2016-17 and 189.7 quintal/ ha in 2017-18) yield was recorded under N_2 and N_0 levels respectively. In case of interactions, highest yield (309.0 and 288.1 quintal/ ha) was recorded under N_2I_3 and lowest (174 and 165 quintal/ ha) under N_0I_0 during both the years of study. The enhanced root yield might be related to sufficient application of N that significantly influenced the plant performance. Boroujerdnia and Ansari, (2007) in lettuce, Aliyu *et al.,* (2007) in onion, and Acar ***et al.,* (**2008) in lettuce have all reported beneficial impacts of N on yield. Higher number of leaves, leaf length, root diameter, net root weight and gross root weight at irrigation level I_3may be attributed to optimal soil

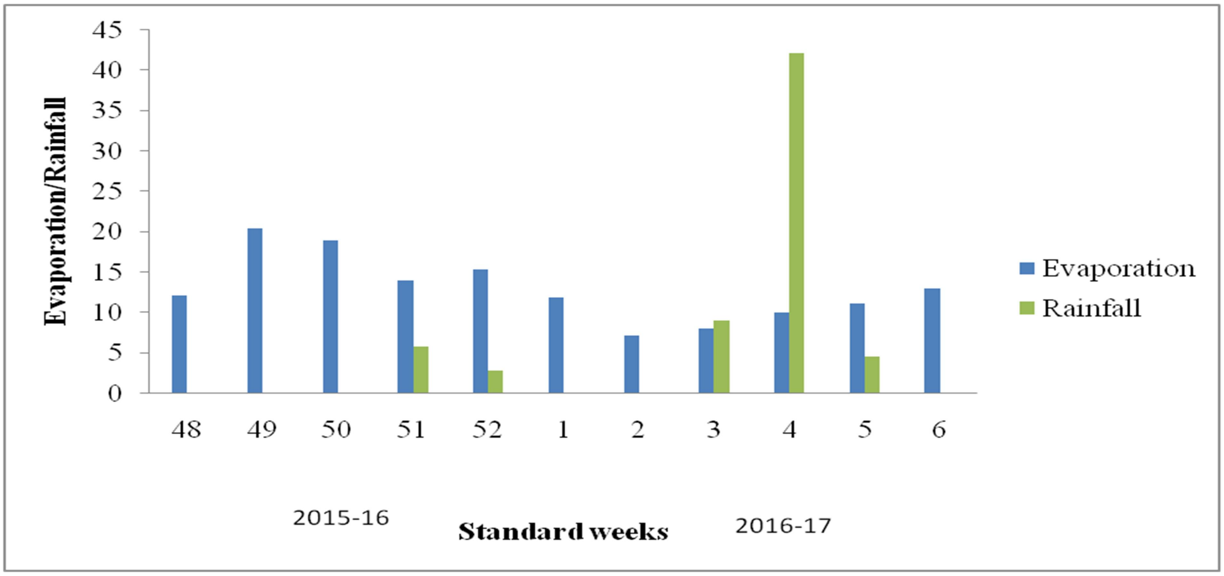

Figure 1: Weekly evaporation and rainfall during the experimentation period 2016-17.

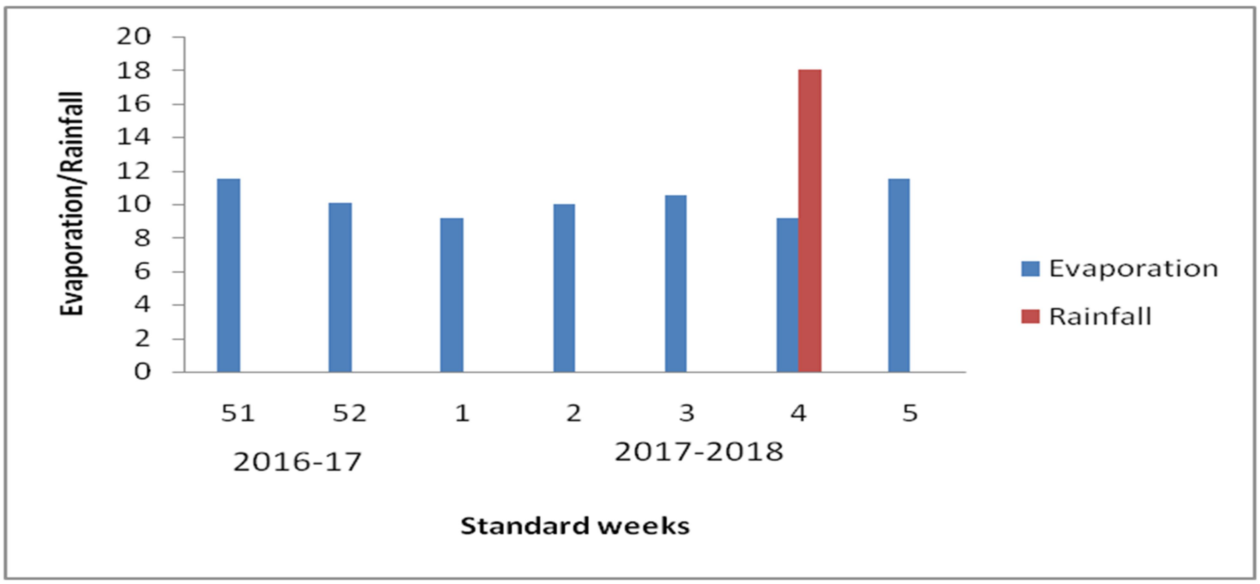

Figure 2: Weekly evaporation and rainfall during the experimentation period 2017-2018.

moisture regimes throughout the growing season, which may have promoted more nutrient uptake and provided the plant with a better soil physical environment to aid in vegetative development and production.Water is the only factor that has a direct impact on the vegetative yield (Siddiqui, 1995). Similarly, Badr *et al.,* 2012 said that applying N to levels required maximising yield during full irrigation will likely result in poor production when the water deficit is significant enough to suppress yield at the optimum N level. The findings of Goudra and Rokhade, (2001) in cabbage, Imitiyaz *et al.* (2000) in cabbage, Kumar *et al.* (2007) in onion, and Kemal, (2013) in shallot are all in agreement. Singh *et al.* (2010) in potato found that higher irrigation and nitrogen levels resulted in better growth and yield expression. The findings in (Table 3) revealed that irrigation schedules, N levels, and interaction (N×I) had a significant effect on dry matter content during both research years (except in first year for interaction effect).Under irrigation schedules, highest dry matter content

(8.34 and 8.57 %) was recorded under I_3 schedule was statistically at par with I_2 (7.60 and 8.21 %) and lowest (6.88 and 7.19 %) under control (I_0) during 2016-17 and 2017-18, respectively. Among N levels, significantly higher (9.06 and 9.40 %) dry matter content was recorded under N_2 and lower (5.65 and 7.26 %) under control during both the years of study respectively. During 2017-18, in case of interaction effect, highest (10.80 %) dry matter content was recorded with N_2I_3 which was statistically at par with N_2I_2 (9.57 %). Lowest dry matter contents (5.93 %) were recorded under N_1I_0 which was statistically at par with N_0I_3 (6.50 %) and N_0I_2 (7.27 %). Dry matter content under I_3, I_2 and I_1 irrigation schedules were significantly higher over I_0 to the tune of 20.2, 12.2 and 8.4 per cent, respectively. Among N levels, the increase was 43.3 percent in N_2 and 17.8 percent in N_1 over N_0. The dry matter content of radish was found to be positively affected by increased watering frequency and increased N levels. Sujatha and Krishnappa, (1995) also found that increased fertility levels resulted in higher dry matter production, which they attributed to more photosynthate synthesis and translocation.Similar findings in potato were reported by Sharma *et al.* (2002), Hurska and Riflug, (1975), Sharma *et al.* (2002) and Lapa *et al.,*(1990). Greater N levels in radish resulted in increased dry matter accumulation, which could be attributed to better vegetative development (Ndang andSema, 1999).

Benefit-cost ratio

Benefit-cost ratio worked out for different treatment combinations has been presented in Table 4. According to the data, the highest gross income was reported in N_2I_3 (Rs597200) followed by N_2I_2 (Rs 562200), N_2I_1 (Rs 530600) and minimum (Rs 339000) under N_0I_0. Similarily, net returns was maximum (Rs 467748) N_2I_3 under followed by N_2I_2 (Rs 433998) and minimum (Rs 215126) under N_0I_0. The highest B:C ratio (3.61:1) was worked out under N_2I_3 which was rated as the most profitable combination followed by N_2I_2 (3.39:1) whereas lowest (1.74:1) under N_0I_0. Comparatively higher root yield due to better root growth under optimum moisture regimes and nutrient availability under N_2I_3 and N_2I_2 might be the reason for higher B:C ratio. These findings are in agreement with the results reported by Imitiyaz*et al.,*2000 in tomato, Alam *et al.* (2010) in carrot, Himanshu *et al.* (2012) and Sumandeep, (2015) in cabbage and Kumari, (2013) in cauliflower who also reported higher gross returns, net return and B:C ratio under higher frequency of irrigation and N level.

Conclusion

The results of study indicated that irrigation scheduling at 1.2 IW/CPE ratio and application of 100 per cent N significantly enhance the growth and yield of radish. It also provides the maximum benefit-cost ratio of radish. Therefore, it may be concluded from the present investigation that deficient irrigation and deficiency of nitrogen may cause reduction in radish yield and lower the soil productivity. This study would help the farmers to increase the productivity of their lands.

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Conflict of interest

The authors declare that they have no conflict of interest.

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