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

Archana Sharma  
Department of Soil Science and Water Management Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni Solan (HP) India.

Jagjeet Chand Sharma  
Department of Soil Science and Water Management Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni Solan (HP) India.

Krishan Lal Gautam  
Department of Silviculture and Agroforestry Dr Yashwant Singh Parmar University of Horticulture and Forestry NauniSolan (HP) India.

Jigmet Namgial  
Department of Agroforestry Sher-e-kashmir University of Agricultural Sciences and Technology Jammu J&K, India.

**ARTICLE INFO**

| Received : 20 June 2021 |
|--------------------------|
| Revised : 21 November 2021 |
| Accepted : 23 December 2021 |

**Key Words:** Irrigation scheduling, IW/CPE ratio, Mid-hills, Nitrogen levels, Radish

**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. *I₀*, 4 cm irrigation at IW/CPE ratio (*I₁*: 0.8), (*I₂*:1.0), (*I₃*:1.2) and three N levels i.e. *N₀*, (*N₁*:75 per cent of RD) and (*N₂*:100 percent of RD). Results revealed that treatment combination *N₂I₃* 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 *N₀I₀*. The highest B:C ratio (3.61:1) was worked out under *N₂I₃* which was rated as the most profitable combination followed by *N₂I₂* (3.39:1). It can be concluded that among different irrigation schedules, *I₃* and *I₂* schedules were found to be equally good for maintaining optimum soil moisture content as compared to *I₁* and *I₀*. Among different N levels, *N₂* 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...
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 Typic Eutrochrept subgroup. 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)**   |
| Sand (%)                        | 0-15             | 15-30            |
| Silt (%)                        | 58.7             | 59.5             |
| Clay (%)                        | 27.2             | 28.5             |
| 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 $I_0N_0$ 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 $N_0$ 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 $30 \text{ cm} \times 10 \text{ cm}$ on $3 \text{ m} \times 2 \text{ m}$ 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 caliper. 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 $65\pm5^{\circ}\text{C}$ till a constant weight. The dry matter was expressed in percentage using following formula:

\[
\text{Dry matter content (\%)} = \left( \frac{\text{Dry weight (g)}}{\text{Fresh weight (g)}} \right) \times 100
\]

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 | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | Mean  |
|----------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
|                | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) | No Irrigation (control) |
| 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 | 20.7 | 21.4 |

#### Leaf Length (cm)

| Nitrogen levels | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | Mean  |
|----------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| 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 | 23.47 | 24.61 |

#### Root length (cm)

| Nitrogen levels | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | Mean  |
|----------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| 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 | 25.97 | 26.89 |

#### Root diameter (cm)

| Nitrogen levels | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | 2016-2017  | 2017-2018  | Mean  |
|----------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| No Nitrogen (Control) | 3.22 | 3.25 | 3.55 | 3.72 | 3.43 | 3.48 | 3.68 | 3.88 | 3.78 |
| 75 % dose of Nitrogen | 3.88 | 3.75 | 3.88 | 3.92 | 3.87 | 4.08 | 4.25 | 4.35 | 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 | 4.29 | 4.39 | 4.69 |

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

| Nitrogen levels       | 2016-2017  | 2017-2018  | 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 Nitrogen (Control) | 106.5      | 117.5      | 125.8               | 138.8               | 122.2 |
| 75 % dose of Nitrogen | 134.2      | 132.5      | 150.8               | 139.5               | 139.3 |
| 100 % RDN             | 153.8      | 149.2      | 142.5               | 156.2               | 150.4 |
| Mean                  | 131.5      | 133.2      | 139.7               | 144.8               | 137.7 |
| CD (P=0.05) of N      | 14.5       |            |                     |                     |      |
| CD (P=0.05) of I      | 16.6       |            |                     |                     |      |
| CD (P=0.05) N×I       | 28.80      |            |                     |                     |      |
| Gross root weight (g) |            |            |                     |                     |
| No Nitrogen (Control) | 154.3      | 157.9      | 172.6               | 172.6               | 164.3 |
| 75 % dose of Nitrogen | 189.3      | 186.9      | 174.3               | 171.9               | 180.6 |
| 100 % RDN             | 163.6      | 212.3      | 192.6               | 204.6               | 193.3 |
| Mean                  | 169.0      | 185.7      | 179.8               | 183.0               | 178.9 |
| CD (P=0.05) of N      | 18.2       |            |                     |                     |      |
| CD (P=0.05) of I      | 20.9       |            |                     |                     |      |
| CD (P=0.05) N×I       | 36.2       |            |                     |                     |      |
| Yield (q ha⁻¹)        |            |            |                     |                     |
| No Nitrogen (Control) | 174.0      | 206.7      | 227.2               | 226.0               | 207.4 |
| 75 % dose of Nitrogen | 228.7      | 236.0      | 243.0               | 252.0               | 239.9 |
| 100 % RDN             | 251.0      | 265.6      | 288.3               | 309.0               | 278.5 |
| Mean                  | 217.9      | 236.1      | 251.3               | 262.3               | 215.9 |
| CD (P=0.05) of N      | 9.0        |            |                     |                     |      |
| CD (P=0.05) of I      | 10.4       |            |                     |                     |      |
| CD (P=0.05) N×I       | 18.0       |            |                     |                     |      |
| Dry matter content (%)|            |            |                     |                     |
| No Nitrogen (Control) | 5.60       | 5.50       | 5.40                | 6.10                | 5.65  |
| 75 % dose of Nitrogen | 6.82       | 7.53       | 7.93                | 8.43                | 7.68  |
| 100 % RDN             | 8.23       | 8.07       | 9.47                | 10.50               | 9.06  |
| Mean                  | 6.88       | 7.03       | 7.60                | 8.34                | 7.19  |
| CD (P=0.05) of N      | 0.72       |            |                     |                     |      |
| CD (P=0.05) of I      | 0.83       |            |                     |                     |      |
| CD (P=0.05) N×I       | NS         |            |                     |                     |      |
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 N2 and N0 levels respectively. Under irrigation levels, maximum leaf length (29.88 and 25.55 cm) was recorded under I3 schedule and minimum (26.61 and 22.77 cm) under control which was statistically at par with I1 (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 N2I3 which was statistically at par with N3I2 (31.73 cm) while during 2017-18, maximum (29.44 cm) leaf length was recorded under N3I1. Minimum (21.03 and 19.89 cm) leaf length was recorded under N0I0 during both the years, respectively. Leaf length in N2 and N1 being 27.8 and 15.7 percent higher over N0, it is possible that this is related to beneficial effects of nitrogen on cell division, cell expansion, and protein synthesis. Irrigation schedule I3, I2 and I1 significantly increased the leaf length by 10.3, 6.7 and 2.8 percent over I0. 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 I3 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 N2 level and minimum (19.69 and 22.58 cm) under N0 (control) which was statistically at par with N1 (20.08 and 25.89 cm) during both the years of research. In case of interactions during 2016-17, significantly higher (22.21 cm) root length was observed under N2I3 which was statistically at par with N3I2 (21.82 cm) and N2I1 (21.43 cm) while during 2017-18 maximum root length (32.9 cm) was recorded under N3I3. Irrigation schedule I1, I2 and I3 significantly increase root length by 10.0, 6.1 and 2.7 percent over I0. Among N levels, the increase was 21.8 in N2 and 8.9 percent in N1 over N0. 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 I1 was recorded with highest root diameter (4.07 and 4.69 cm) followed by I3 (3.92 and 4.39 cm) and

| 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 |
|------------|-----------------|-------------------|-----------------------------|-----------------------|-----------------------------|-----------------------------|-----------|
| N0I0       | 21200           | 102674            | 123874                      | 169.5                 | 339000                      | 215126                      | 1.74      |
| N0I1       | 21200           | 105174            | 126374                      | 193.7                 | 387400                      | 261026                      | 2.07      |
| N0I2       | 21200           | 106424            | 127624                      | 212.7                 | 425400                      | 297776                      | 2.33      |
| N0I3       | 21200           | 107674            | 128874                      | 218.2                 | 436400                      | 307526                      | 2.39      |
| N1I0       | 21200           | 103108            | 124308                      | 226                   | 452000                      | 327692                      | 2.64      |
| N1I1       | 21200           | 105608            | 126808                      | 234                   | 468000                      | 341192                      | 2.69      |
| N1I2       | 21200           | 106858            | 128058                      | 245.3                 | 490600                      | 362542                      | 2.83      |
| N1I3       | 21200           | 108113            | 129313                      | 253.7                 | 507400                      | 378087                      | 2.92      |
| N2I0       | 21200           | 103252            | 124452                      | 255.3                 | 510600                      | 386148                      | 3.10      |
| N2I1       | 21200           | 105752            | 126952                      | 265.3                 | 530600                      | 403648                      | 3.18      |
| N2I2       | 21200           | 107002            | 128202                      | 281.1                 | 562200                      | 433998                      | 3.39      |
| N2I3       | 21200           | 108252            | 129452                      | 298.6                 | 597200                      | 467748                      | 3.61      |
minimum (3.73 and 4.13 cm) was under control (I₀). Under N levels, significantly highest (4.30 and 5.00 cm) and lowest (3.43 and 3.78 cm) root diameter was recorded with N₂ and N₀ level, respectively. In case of interactions, N₁N₂ was recorded with maximum (4.58 and 5.28 cm) root diameter while N₀N₀ 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 N₂ which was 28.8 percent higher than N₀ (3.61 cm) followed by N₁ (4.12 cm) which was 14.1 percent higher over N₀. In case of interactions, maximum root diameter (4.93 cm) was recorded with N₂I₁ while lowest (3.35 cm) under N₀I₀ which was statistically at par with N₀I₁ (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 165.3 g) net root weight was recorded under I₂ followed by I₁ (139.7 and 152.4 g) and lowest (131.5 and 137.7 g) under I₀ during both the years of study. Among N levels, significantly higher (150.4 and 181.8 g) net root weight was recorded with N₁ and lower (122.2 and 121.4 g) under N₀ (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 N₁N₂ and N₀I₀. Irrigation schedules I₁, I₂ and I₁ 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 (I₀). Among N levels, the increase was 36.4 percent in N₂ and 17.2 percent in N₁ over the control (N₀). 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 I₁ followed by I₃ (183.0 g) and lower (169.0 g) under control (I₀). Among N levels, N₂ level was recorded with highest (193.3 g) gross root weight which was statistically at par with N₁ (180.6 g) and lowest (164.3 g) under control (N₀) during 2016-17. During 2017-18, highest (311.2 g) gross root weight was recorded with I₃ schedule and lowest (268.2 g) under control (I₀). Under N levels, significantly higher (337.0 g) and lower (239.0 g) gross root weight was recorded under N₂ and N₀ 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 N₁I₁ and lower (154.3 and 213.3 g) under control (N₀I₀) during 2016-17 and 2017-18, respectively. The higher net and gross root weight at irrigation schedule I₃ 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 I₁ schedule which was statistically at par with I₂ (251.3 and 241.4 quintal/ha) and lower (217.9 and 215.9 quintal/ha) under control (I₀) 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 N₂ and N₀ levels respectively. In case of interactions, highest yield (309.0 and 288.1 quintal/ha) was recorded under N₁I₁ and lowest (174 and 165 quintal/ha) under N₀I₀ during both the years of study. The enhanced root yield might be related to sufficient application of N that significantly influenced the plant performance. Boroujerdia 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 I₃ may be attributed to optimal soil
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 I3 schedule was statistically at par with I2 (7.60 and 8.21 %) and lowest (6.88 and 7.19 %) under control (I0) during 2016-17 and 2017-18, respectively. Among N levels, significantly higher (9.06 and 9.40 %) dry matter content was recorded under N2 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 N2I3 which was statistically at par with N2I2 (9.57 %). Lowest dry matter contents (5.93 %) were recorded under N1I0 which was statistically at par with N0I3 (6.50 %) and N0I2 (7.27 %). Dry matter content under I3, I2 and I1 irrigation schedules were significantly higher over I0 to the tune of 20.2, 12.2 and 8.4 per cent, respectively. Among N levels, the increase was 43.3 percent in N2 and 17.8 percent in N1 over N0. 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 and Sema, 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 N2I3 (Rs597200) followed by N2I2 (Rs 562200), N3I1 (Rs 530600) and minimum (Rs 467748) under N0I0. Similarly, net returns was maximum (Rs 433998) and minimum (Rs 215126) under N0I0. The highest B:C ratio (3.61:1) was worked out under N2I3 which was rated as the most profitable combination followed by N2I2 (3.39:1) whereas lowest (1.74:1) under N0I0. Comparatively higher root yield due to better root growth under optimum moisture regimes and nutrient availability under N2I3 and N2I2 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.

**Acknowledgement**

The authors are thankful to the Director of research Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan HP India for the necessary facilities and financial support to conduct the study.

**Conflict of interest**

The authors declare that they have no conflict of interest.

**References**

Acar, B., Paksoy, M., Türkmen, O., & Seymen, M. (2008). Irrigation and nitrogen level affect lettuce yield in greenhouse condition. *African Journal of Biotechnology*, 7(24).

Aalam, M. S., Mallik, S. A., Costa, D. J., & Alam, A. (2010). Effect of irrigation on the growth and yield of (Daucuscarota ssp. sativus) carrot in hill valley. *Bangladesh Journal of Agricultural Research*, 35(2), 323-329.

Ali, M. K., Barkotulla, M. A. B., Alam, M. N., & Tawab, K. A. (2006). Effect of nitrogen levels on yield and yield contributing characters of three varieties of carrot. *Pakistan Journal of Biological Sciences*, 9(3), 553-557.

Aliyu U., Magaji, M.D., Singh, A., & Mohammed, S.G. (2007). Growth and yield of onion (*Allium cepa L.*) as influenced by nitrogen and phosphorus levels. *International Journal of Agriculture Research*, 2(1), 937-944.
Amiri, E., Gohari, A. A., & Esmailian, Y. (2012). Effect of irrigation and nitrogen on yield, yield components and water use efficiency of eggplant. *African Journal of Biotechnology, 11*(13), 3070-3079.

Baloche, P. A., Riaz, U., Nizamani, F. K., Solangi, A. H., & Siddiqui, A. A. (2014). Effect of nitrogen, phosphorus and potassium fertilizers on growth and yield characteristics of radish (Raphanus sativus L.). *American-Eurasian Journal of Agricultural & Environmental Sciences, 14*(6), 565-569.

Bhattacharya, S., Alvino, A., Loreto, F., Centritto, M., & Santarelli, A. (2009). Effect of paired row planting on drip irrigated cabbage (Brassica oleracea) in a semi-arid region of India. *Journal of Agricultural Research, 53*(7), 443-448.

Bhuiya, M. A. K., Rahim, M. A., & Chowdhury, M. N. A. (2003). Effect of planting time, mulch and irrigation on the growth and yield of garlic. *Asian Journal of Plant Sciences, 2*, 639-643.

Boroujerdnia, M., & Ansari, N.A. (2007). Effect of different levels of nitrogen fertilizer and cultivar on growth, yield and yield component of Romaine lettuce (lactuca sativa L.). *Middle Eastern and Russian Journal of Plant Science and Biotechnology, 1*, 47-53.

Boyer, J. S. (1982). Plant productivity and environment. *Science, 218*(4571), 443-448.

Brintha, I., & Seran, T. H. (2009). Effect of paired row planting of radish (Raphanus sativus L.) intercropped with vegetable amaranthus (Amaranthus tricolor L.) on yield components of radish in sandy regosol. *4*, 19-28.

Chowdhury, S. A., Quadir, M. A., Karim, A. J. M. S., Molla, M. S., & Shamim, R. U. (1999). Response of carrot to different moisture regimes. *Bangladesh Journal of Agricultural Research, 24*(2), 279-285.

Delfine, S., Alvino, A., Loreto, F., Centritto, M., & Santarelli, G. (1999, June). Effects of water stress on the yield and photosynthesis of field-grown sweet pepper (*Capsicum annuum* L.). In *III International Symposium on Irrigation of Horticultural Crops* 537 (pp. 223-229).

Food and Agriculture Organization of the United Nations., 2000. Deficit irrigation practices. *23 Dec. 2010*

Goudra, K. H. B., & Rokhade, A. K. (2001). Effect of irrigation schedules and methods on growth and yield of cabbage. *Karnataka Journal of Agricultural Sciences, 14*(3), 721-723.

Himanshu, S. K., Kumar, S., Kumar, D., & Mokhtar, A. (2012). Effects of lateral spacing and irrigation scheduling on drip irrigated cabbage (Brassica oleracea) in a semi-arid region of India. *Research Journal of Engineering Sciences ISSN, 2278, 9472.*

Hruskha, L., & Rflug, L. (1975). Effect of spacing and fertilization on some quality indices of potato tuber. *Acta Universitatis Brno Facultas Agronomica, 23*(3), 15-321.

Huang, W. Y. (2002). Using insurance to enhance nitrogen fertilizer application timing to reduce nitrogen losses. *Journal of Agricultural and Applied Economics, 34*(1), 131-148.

Imtiyaz, M., Mgdala, N. P., Chepete, B., & Manase, S. K. (2000). Response of six vegetable crops to irrigation schedules. *Agricultural water management, 45*(3), 331-342.

Islam, M. T., Rahman, M. H., Yeasmin, R., Mamun, M. A. A., & Rahman, M. A. (2015). Effect Of Number Of Plant Per Hill And Irrigation Intervals on. *Journal of Science and Technology, 112*, 117.

Jilani, M.S., Burki, T., & Waseem, K. (2010). Effect of nitrogen on growth and yield of radish. *Journal of Agricultural Research, 48*, 219-225.

Kashyap, P. S., & Panda, R. K. (2003). Effect of irrigation scheduling on potato crop parameters under water stressed conditions. *Agricultural water management, 59*(1), 49-66.

Kemal, Y. O. (2013). Effects of irrigation and nitrogen levels on bulb yield, nitrogen uptake and water use efficiency of shallot (*Allium cepa* var. ascalonicum Baker). *African Journal of Agricultural Research, 8*(37), 4637-4643.

Kumar, S., Imtiyaz, M., Kumar, A., & Singh, R. (2007). Response of onion (*Allium cepa* L.) to different levels of irrigation water. *Agricultural Water Management, 89*(1-2), 161-166.

Kumari, M., & Devi, M. (2013). Scheduling of irrigation in cauliflower (*Brassica oleracea* var. botrytis L.) under mid hill conditions of Himachal Pradesh (Doctoral dissertation, M. Sc. Thesis. Department of Soil Science and Water Management, Dr Yaswant Singh Parmar University of Horticulture and Forestry, Solan. 81p).

Lapa, V.V., Limantowa, E.M., Rybik, O.F., Lashukench, O.M., Lukashenek, Z.N., &Kovallenok, M.F., 1990. Effect of increasing doses of N fertilizer on productivity and quality of potatoes in desopodzolic soils of Belarui.Agrokhimzya, 45, 631-6.

Moniruzzaman, M., Akand, M. H., Hossain, M. I., Sarkar, M. D., & Ullah, A. (2013). Effect of Nitrogen on the Growth and Yield of Carrot (*Daucus carota* L.). *The Agriculturists, 11*(1), 76-81.

Olczyk, T., Regalado, R., Li, Y. C., & Jordan, R. (2000). Usefulness of tensiometers for scheduling irrigation for tomatoes grown on rocky, calcareous soils in Southern Florida. In *Proceedings of the Florida State Horticultural Environment Conservation Journal*
Panse, V. G., & Sukhatme, P. V. (1954). Statistical methods for agricultural workers. *Statistical methods for agricultural workers.*

Sadia, A. A., Mahasen, M., Shahrin, S., Roni, M. Z. K., & Uddin, A. F. M. (2013). Phosphorus levels on growth and yield of turnip (*Brassica campestris* var. *rapifera*). *Bangladesh Research Publications Journal, 8*(1), 29-33.

Sharma, R. C., & Sood, M. C. (2002). Nitrogen and potassium interaction on the tuber yield, quality and organic carbon status of Shimla soils. In *Potato, global research & development. Proceedings of the Global Conference on Potato, New Delhi, India, 6-11 December, 1999: Volume 2* (pp. 843-851). Indian Potato Association

Siddiqui, A.B.(1995). Local adaptability and suitability of vegetable and spice crop-In: Training manual winter vegetable and spice. Ed. M MofizulHaque.Horticulture research and development project.FAO/UN/AsDB in collaboration with DAE, BADC, Dhaka 62-74p.

Sood, M. C., & Singh, S. P. (2010). Optimizing irrigation water and nutrient requirement of potato (*Solanumtuberosum* L.) under drip fertigation. *Progressive Agriculture, 10*(1), 192-195.

Sujatha, N. T., & Krishnappa, K. S. (1995). Effect of different fertility levels on dry matter production at different stages of growth and nutrient uptake of potato. *Journal of the Indian Potato Association (India).*

Sumandeep., (2015). Effect of irrigation schedules and nitrogen levels on growth and yield of cabbage (*Brassica oleracea var. capitata* L.). M.Sc. Thesis. Department of Soil Science and Water Management, Dr. YS Parmar University of Horticulture and Forestry, Solan.43p.

Tripathi, A. K., Ram, R. B., Rout, S., Kumar, A., & Patra, S. (2017). Effect of Nitrogen Levels and Spacing on Growth and Yield of Radish (*Raphanus sativus* L.) Cv. Kashi Sweta. *International pure applied bio science, 5*(4), 1951-1960.

Wahocho, N. A., Wahocho, S. A., Memon, N., Leghari, M. H., & Baloch, Q. B. (2016). Growth and yield response of turnip to various nitrogen application rates. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences, 32*(2), 143-149.

Wang, F. X., Kang, Y., & Liu, S. P. (2006). Effects of drip irrigation frequency on soil wetting pattern and potato growth in North China Plain. *Agricultural water management, 79*(3), 248-264.

**Publisher's Note:** ASEA remains neutral with regard to jurisdictional claims in published maps and figures.