Original Research Article

Effect of Irrigation and Nitrogen Levels on Nutrient Uptake, Water Use Efficiency and Productivity of Onion (Allium cepa L.) in Himachal Pradesh

Samir Bhatti*, J.C. Sharma and Ridham Kakar

Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP) 173230, India

*Corresponding author

A B S T R A C T

Field experiments were conducted during 2015-16 and 2016-17 to study the effect of irrigation and N levels on nutrient uptake, water use efficiency and productivity of onion (Allium cepa L.) in Himachal Pradesh. Twelve treatment combinations comprising four irrigation level i.e. 4 cm irrigation at IW/CPE ratio 1.2 (I1), 1.0 (I2), 0.8 (I3), 0.6 (I4) and three N levels i.e. 75 (N1), 100 (N2) and 125 per cent (N3) of recommended dose of N, were replicated thrice in a Randomized Block Design. Nutrient uptake and bulb yield were at par under I1 and I2 levels and both these levels exhibited higher WUE, (115.1 and 104.9 kg ha⁻¹mm⁻¹) was recorded under I1 followed by I2 (109.7 and 104.6 kg ha⁻¹mm⁻¹) with (35.42 and 39.14 cm) and (34.45 and 37.29 cm) of total water requirement during both the years of study, hence I2 was considered as efficient irrigation level. Among N levels, N3 was found to be optimum as it recorded significantly higher productivity of onion crop over N2 and N1 levels. Pooled analysis of the data showed that the combinations of I1N3 and I2N3 gave significantly higher bulb yield (467.0 q ha⁻¹ and 435.5 q ha⁻¹) and were noted to be 53.7 and 43.3 per cent higher over I4N1. The study led to a conclusion that the combination of irrigation level I2 (4 cm irrigation at 1.0 IW/CPE) with N3 level (125% of RD of N) (I2N3) could be the best for maximising yield of onion with efficient use of scarce irrigation water in Himachal Pradesh.

Keywords
Onion, Irrigation and nitrogen levels, Nutrient uptake, Crop productivity, Water requirement, Water use efficiency

Article Info
Accepted: 04 January 2019
Available Online: 10 February 2019

Introduction

Onion is an important crop of Himachal Pradesh, but the productivity of the crop is quite low owing to lack of assured availability of irrigation water, sub optimal and imbalanced use of fertilizer nutrients, improper management of soil and water resources and inadequate crop management practices, weed control and plant protection measures, etc. Among various factors involved, nutrient and moisture supply are important inputs for realizing higher onion yield. Irrigation scheduling is a critical management input to ensure optimum soil moisture regime for proper growth and development as well as for optimum yield and economic benefits. Well managed irrigation can lead to increased yields, greater farmer profit, and significant water savings, reduced
environmental impacts and improved sustainability of irrigated agriculture (Evett et al., 2011; Gill et al., 2011). It has been documented that effect of irrigation and nitrogen is negligible if proper irrigation schedule is not followed. Irrigation scheduling and nitrogen levels in accordance with crop sensitivity to irrigation and nutrients during the growing cycle can hide the effects of other growth and yield affecting factors, such as rainfall amount and distribution pattern. Present study, therefore, was undertaken to determine optimum irrigation schedule and nitrogen level to achieve higher productivity of onion in Himachal Pradesh.

**Materials and Methods**

Field experiments were conducted during two crop years (2015-2016) at the experimental farm of Department of Soil Science and WM, Dr YS Parmar University of Horticulture and Forestry, Solan (HP). The soil (Typic Eutrochrept) was gravelly loam in texture. Salient physical and chemical properties of the experimental soil of 0-15 cm depth were pH 6.91, organic carbon (%) 0.93, available N, P and K 245.30, 33.16 and 260.20 kg ha$^{-1}$, respectively. Moisture retention at FC and PWP were 24.05 and 7.5 per cent in 0-15 cm depth, respectively. The experiment was laid out with 12 treatments replicated thrice in randomized block design. Recommended dose (100%) of FYM, N, P$_2$O$_5$ and K$_2$O is 25 t ha$^{-1}$, 125, 75 and 60 kg ha$^{-1}$, respectively, and were applied as per the treatments of the experiment in the form of Urea, single super-phosphate and muriate of potash. Entire dose of FYM, P and K fertilizers was applied at the time of field preparation. The N fertilizer was applied in two split doses, first dose at the time of transplanting and second dose one month after transplanting and third dose two months after transplanting. Soil moisture contents in 0-7.5 and 7.5-15 cm depths were determined before and 24 hours after each irrigation to know the moisture regimes under different irrigation levels and the data has been presented for both the years of study. Leaf samples were collected and processed according to the method suggested by Chapman (1964). The nutrient contents were determined following standard methods for the analysis. The uptake of nutrients was calculated from data on contents (%) of the given nutrient in root, leaf and bulb multiplied by the corresponding dry matter yield. The data of each parameter for two crop seasons (2015-16 and 2016-17) have been presented.

**Results and Discussion**

**Soil moisture contents before and after irrigation**

Maximum soil moisture contents was noticed under I$_1$ (4 cm irrigation at 1.2 IW/CPE ratio) irrigation level which ranged from 22.46-27.24 and 22.78-28.45 per cent with mean values of 25.94 and 26.27 per cent, which was slightly higher than the field capacity during both the years (Table 1). Minimum soil moisture contents were recorded in I$_4$ (4 cm irrigation at IW/CPE ratio 0.6) irrigation level which ranged from 17.79-21.88 and 18.79-22.97 per cent with mean values of 19.72 and 20.88 per cent, which was 18.0 and 13.5 per cent lower than the field capacity during the year 2016 and 2017, respectively. In 7.5-15 cm depth after irrigation mean values varied from 17.60-22.80 and 18.10-23.60 per cent during the year 2016 and 2017, respectively.
IW/CPE ratio 0.6) irrigation level which ranged from 15.78-19.12 and 16.48-19.72 per cent with mean values of 17.60 and 18.10 per cent, which were 26.8 and 24.7 per cent lower than the field capacity during the year 2016 and 2017, respectively. Higher soil moisture contents under I₁ and I₂ irrigation level were due to frequent irrigations, whereas, comparatively lower moisture contents under I₃ and I₄ treatment were due to longer interval between successive irrigations. Higher moisture contents due to higher frequency of irrigations did not show any visual stress on various physiological processes, resulting in better uptake of nutrients and finally increased plant growth; yields attributes and yield (Kuchenbuch et al., 2006; Patel et al., 2008; Kumari, 2013).

Available NPK in soil

Irrigation as well as N levels and their interaction exhibited significant effect on available N, P and K in 0-15 cm soil depth (Table 2-4). Maximum contents of available N (365.5 and 357.6 kg ha⁻¹), P (57.23 and 53.29 kg ha⁻¹) and K (377.1 and 376.6 kg ha⁻¹) were recorded under I₁ followed by I₂ and these were significantly higher over I₃ and I₄ during both the years of study. Among N levels, N₃ recorded higher available N, P and K, i.e. (385.9 and 358.4 kg ha⁻¹), (53.74 and 49.34 kg ha⁻¹), and (374.5 and 367.6 kg ha⁻¹) which were at par with N₂ and significantly higher over N₁. Interactions between irrigation and N levels were also significant and maximum contents of N (400 and 402.7 kg ha⁻¹), P (63.67 and 59.93 kg ha⁻¹) and K (410.7 and 396.9 kg ha⁻¹) were recorded under I₁N₃ which were at par with I₂N₃ and significantly higher over other treatment combinations. Higher availability of N with increasing levels of N is quite obvious and might be due to favourable soil moisture regimes and the positive effect of irrigation schedules and N levels. Nitrogen, as nitrate and ammonium is highly soluble and moves rapidly in soil and thus available N increased with favourable soil moisture contents. The significant build-up of the available N due to N application could also be attributed to increased activity of nitrogen fixing bacteria thereby resulting in higher accumulation of nitrogen in soil (Kumar, 2002). Increase in available P contents with increasing levels of N might be due to lower utilization of applied P by the crop resulting in build up of soil P status. Another possible reason for increase in P contents may be partly attributed to the activity of certain P solubilising microbes which are more in soils having high OC contents and adequate soil moisture thus releasing organic acids which are responsible for conversion of unavailable P to available form as well as the mineralization of soil organic matter/FYM by the microbes which also contribute to the pool of P (Lapeyne et al., 1991). The enhanced status of soil K could be due to high native K and increased moisture contents.

Nutrient uptake

Irrigation and N levels had significantly enhanced the uptake of N, P and K (Table 5-7). Irrigation levels I₁ and I₂, showed increased uptake of N (109.03 and 105.82 kg ha⁻¹) and (92.47 and 92.48 kg ha⁻¹), P (21.65 and 20.46 kg ha⁻¹) and K (104.5 and 106.5 kg ha⁻¹) which were at par with N₂ and significantly higher over N₁. This might be due to better root growth conditioned by favourable moisture regimes, thereby resulting in higher uptake of applied nutrients. Higher uptake of P and K associated with enlarged root system and higher soil moisture regimes has also been reported by Guimera et al., (1995) and Raman Murthy and Reddy (2013). Nitrogen levels N₃ recorded significantly higher uptake of N (99.15 and 99.12 kg ha⁻¹), P (19.36 and 19.40 kg ha⁻¹) and K (95.6 and 100.8 kg ha⁻¹).
over N2 and N1. Higher availability of nutrients as well as higher yield could be attributed for the higher uptake of nutrients. These results are in line with the findings of Hara and Saha (2000), Kemal (2013) and Al-Solaimani and Bakshi (2002), who also observed higher uptake of N with the increase in N application in tomato, onion and cabbage, respectively. Interactive effect of irrigation schedules and N levels on N, P and K uptake was found to be significant. Significantly higher N, P and K uptake was observed in I1N3 (127.81 and 126.36 kg ha⁻¹), P (24.91 and 23.84 kg ha⁻¹) and K (120.5 and 126.7 kg ha⁻¹) and I2N3 (110.81 and 105.59 kg ha⁻¹), P (22.52 and 21.46 kg ha⁻¹) and K (107.6 and 107.7 kg ha⁻¹) over I1N1. Irrigation levels I1 and I2 with higher levels of N application led to higher nutrient availabilities which might have been utilized efficiently by the crop and produced higher yield resulting higher nutrient uptake. Higher uptake of N might have been due to favourable moisture regimes which in turn allowed greater proliferation of roots, thereby facilitating higher absorption of nutrients and water from the soil. Nitrogen to be available to growing crops, the soil moisture must be sufficient to allow nitrates to move to the roots. However in dry soil, optimal quantities of N could not reach to the plant roots, indicating that N utilization was influenced by soil moisture status during the growing season.

**Bulb yield**

Irrigation levels exerted significant impact on bulb yield of onion (Table 8). Significantly higher (407.8 q ha⁻¹ and 410.7 q ha⁻¹) and lower (327.0 q ha⁻¹ and 307.8 q ha⁻¹) bulb yield was recorded under I1 and I4, respectively as compared to other irrigation levels, during both the years of study. Among N levels, maximum bulb yield (406.5 q ha⁻¹ and 408.8 kg ha⁻¹) and minimum (336.8 q ha⁻¹ and 332.7q ha⁻¹) was recorded under N3 and N1 levels, during both the years of study. In case of interaction (I×N) significantly higher bulb yield (462.7 q ha⁻¹ and 471.3 q ha⁻¹) was recorded under I1N3 and lower (306.0 q ha⁻¹ and 305.3 q ha⁻¹) under I4N1 which was found to be at par with I4N2 (316.7 q ha⁻¹ and 305.3 q ha⁻¹) treatment combination during both the years. Pooled analysis showed that the effect of irrigation and N levels was significant and the trend was almost similar during both the years of study. Maximum (409.2 q ha⁻¹) and minimum bulb yield (317.4 q ha⁻¹) was recorded under I1 and I4, respectively over other irrigation levels, whereas maximum bulb yield (407.7 q ha⁻¹) and minimum bulb yield (334.3 q ha⁻¹) was recorded under N3 and N1, respectively as compared to other N levels. In case of interaction of irrigation and N levels (I×N) maximum bulb yield (467.0 q ha⁻¹) was recorded under 1.2 IW/CPE ratio and supplied with 125 per cent N (I1N3) and minimum (303.7 q ha⁻¹) under 0.6 IW/CPE ratio with 75 per cent N (I4N1). The highest bulb yield at irrigation levels I1 and I2 might be due to optimum soil moisture regimes (Table 1) throughout the growing period which might have facilitated greater nutrient uptake and proper soil physical environment to help the plants to put forth better vegetative growth, leading to higher bulb growth and yield. The present results are in accordance with the earlier findings of Lorenz and Maynard (1980), Adentuji (1990) and Lingaiah et al., (2005) and Bungard et al., (1999) in onion. In the present findings also, better performance of all the components as a result of optimum soil moisture provided by appropriate quantity of water at desired interval might have resulted in steady active plant growth and maximum possible yield. Rathore and Singh (2009) also emphasized the importance of irrigation at appropriate time as plant tissue contains more than 95 per cent of water which should be maintained for keeping the plant photosynthetically active resulting in proper growth and development.
and ultimately yield. Higher yield of onion in N₃ might be due to complete solubility, mobilization and availability of N at regular interval in required quantity due to split application. Similar results were also reported by Sharma et al., (2009) in onion, Gulsum et al., (2010) in lettuce, Goudra and Rokhade (2001) in cabbage, Alam et al., (2010) in carrot, Singh et al., (2010) in potato and Tolga et al., (2010) in broccoli. Favourable effects of N on yield of tomato and eggplant have also been reported by Hegde and Srinivas (1989) and Rahman et al., (2007). The reasons suggested for such a response was that optimum N application increased growth parameters, which in return synthesized more plant metabolites thereby increased crop yield.

Table 1 Effect of irrigation levels on soil moisture contents (0-7.5 cm and 7.5-15 cm depths) during the year 2016 and 2017

| Treatments | Moisture contents (% ,w/w) |
|------------|----------------------------|
|            | 0-7.5 cm depth | 7.5-15 cm depth |
|            | Before irrigation | After Irrigation | Before irrigation | After Irrigation |
| I₁ Range   | 2016 10.92-16.44 | 22.46-27.24 | 11.44-17.62 | 18.14-24.32 |
|            | 2017 11.77-16.69 | 22.78-28.45 | 12.52-17.92 | 19.74-25.12 |
| Mean       | 2016 14.96 | 25.94 | 16.22 | 22.80 |
|            | 2017 15.10 | 26.27 | 16.46 | 23.60 |
| I₂ Range   | 2016 10.22-14.08 | 21.12-26.84 | 11.14-15.96 | 18.14-23.94 |
|            | 2017 10.52-14.12 | 21.26-27.14 | 11.84-15.76 | 18.66-24.24 |
| Mean       | 2016 13.12 | 24.14 | 14.20 | 21.86 |
|            | 2017 13.24 | 24.58 | 14.16 | 22.26 |
| I₃ Range   | 2016 10.02-13.12 | 20.88-24.24 | 10.08-13.34 | 17.16-21.16 |
|            | 2017 10.16-13.18 | 20.18-24.44 | 10.84-13.74 | 17.46-21.96 |
| Mean       | 2016 11.04 | 22.48 | 12.36 | 18.86 |
|            | 2017 11.12 | 22.84 | 12.64 | 19.18 |
| I₄ Range   | 2016 9.84-11.22 | 17.79-21.88 | 9.96-12.54 | 15.78-19.12 |
|            | 2017 9.64-11.04 | 18.79-22.97 | 10.06-12.87 | 16.48-19.72 |
| Mean       | 2016 10.48 | 19.72 | 11.24 | 17.60 |
|            | 2017 10.34 | 20.88 | 11.46 | 18.10 |
Table 2 Effect of irrigation and N levels on available soil N (kg ha\(^{-1}\))

| Treatments | 2015-16 | 2016-17 | Pooled |
|------------|---------|---------|--------|
|            | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean |
| I1         | 325.0 | 371.6 | 400.0 | 365.5 | 301.3 | 368.7 | 402.7 | 357.6 | 313.2 | 370.2 | 401.3 | 361.6 |
| I2         | 282.0 | 368.3 | 393.3 | 347.9 | 289.3 | 351.0 | 385.3 | 341.9 | 285.7 | 359.7 | 389.3 | 344.9 |
| I3         | 246.0 | 358.0 | 377.0 | 327.0 | 266.7 | 315.3 | 336.0 | 306.0 | 256.3 | 336.7 | 356.5 | 316.5 |
| I4         | 236.0 | 330.7 | 372.0 | 312.9 | 265.0 | 298.7 | 309.7 | 291.1 | 250.5 | 314.7 | 340.8 | 302.0 |
| Mean       | 272.5 | 357.2 | 385.9 | 338.3 | 280.6 | 333.4 | 358.4 | 324.4 | 276.4 | 345.3 | 372.0 | 331.2 |
| CD\((0.05)\) |       |       |       |       |       |       |       |       |       |       |       |       |
| I          | 7.23  |        |       | 7.03  |        |       | 4.22  |
| N          | 6.27  |        |       | 6.09  |        |       | 3.65  |
| I×N        | 12.53 | 12.18  |       | 7.31  |        |       |       |

I1: (1.2 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (0.8 IW/CPE ratio), I4: (0.6 IW/CPE ratio)
N1: 75 % of recommended dose of N, N2: Recommended dose of N, N3: 125 % of recommended dose of N

Table 3 Effect of irrigation and N levels on available soil P (kg ha\(^{-1}\))

| Treatments | 2015-16 | 2016-17 | Pooled |
|------------|---------|---------|--------|
|            | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean |
| I1         | 50.00 | 58.03 | 63.67 | 57.23 | 46.40 | 53.93 | 59.53 | 53.29 | 48.20 | 55.98 | 61.60 | 55.26 |
| I2         | 47.20 | 53.93 | 61.13 | 54.09 | 44.13 | 51.13 | 57.13 | 50.80 | 45.67 | 52.53 | 59.13 | 52.44 |
| I3         | 43.93 | 46.63 | 53.33 | 47.97 | 40.40 | 42.83 | 47.67 | 43.63 | 42.17 | 44.73 | 50.50 | 45.80 |
| I4         | 38.00 | 45.07 | 36.83 | 39.97 | 37.67 | 40.80 | 33.03 | 37.17 | 37.83 | 42.93 | 34.93 | 38.57 |
| Mean       | 44.78 | 50.92 | 53.74 | 49.81 | 42.15 | 47.18 | 49.34 | 46.22 | 43.47 | 49.05 | 51.54 | 48.02 |
| CD\((0.05)\) |       |       |       |       |       |       |       |       |       |       |       |       |
| I          | 1.68  |        |       | 1.50  |        |       | 1.48  |
| N          | 1.46  |        |       | 1.30  |        |       | 1.28  |
| I×N        | 2.91  | 2.60  |       | 2.56  |        |       |       |

I1: (1.2 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (0.8 IW/CPE ratio), I4: (0.6 IW/CPE ratio)
N1: 75 % of recommended dose of N, N2: Recommended dose of N, N3: 125 % of recommended dose of N

Table 4 Effect of irrigation and N levels on available soil K (kg ha\(^{-1}\))

| Treatments | 2015-16 | 2016-17 | Pooled |
|------------|---------|---------|--------|
|            | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean | N1  | N2  | N3  | Mean |
| I1         | 336.0 | 384.7 | 410.7 | 377.1 | 342.7 | 390.7 | 396.9 | 376.6 | 339.3 | 387.5 | 403.8 | 376.9 |
| I2         | 316.3 | 374.0 | 387.6 | 359.3 | 323.5 | 367.6 | 377.7 | 356.1 | 319.9 | 370.8 | 382.4 | 357.7 |
| I3         | 289.5 | 350.7 | 356.7 | 332.3 | 283.6 | 341.3 | 358.3 | 327.8 | 286.6 | 346.0 | 357.5 | 330.0 |
| I4         | 270.3 | 330.7 | 343.3 | 314.7 | 277.0 | 321.6 | 337.9 | 312.2 | 273.7 | 326.2 | 340.5 | 313.4 |
| Mean       | 303.1 | 360.0 | 374.5 | 345.9 | 306.7 | 355.2 | 367.6 | 343.2 | 304.9 | 357.6 | 371.1 | 344.5 |
| CD\((0.05)\) |       |       |       |       |       |       |       |       |       |       |       |       |
| I          | 3.8   |        |       | 2.9   |        |       | 2.7   |
| N          | 3.3   |        |       | 2.5   |        |       | 2.3   |
| I×N        | 6.6   | 5.0    |       | 4.6   |        |       |       |

I1: (1.2 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (0.8 IW/CPE ratio), I4: (0.6 IW/CPE ratio)
N1: 75 % of recommended dose of N, N2: Recommended dose of N, N3: 125 % of recommended dose of N
Table 5: Effect of irrigation and N levels on total N uptake (kg ha\(^{-1}\)) in onion

| Treatment | 2015-16 | 2016-17 | Pooled |
|-----------|---------|---------|--------|
|           | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  |
| I\(_1\)   | 92.64   | 106.64  | 127.81  | 109.03  | 84.88  | 106.21  | 126.36  | 105.82  | 88.76  | 106.42  | 127.09  | 107.42  |
| I\(_2\)   | 76.18   | 90.42   | 110.81  | 92.47   | 74.14  | 97.71   | 105.59  | 92.48   | 75.16  | 94.06   | 108.20  | 92.48   |
| I\(_3\)   | 67.98   | 79.01   | 79.33   | 75.44   | 65.83  | 82.55   | 87.99   | 78.79   | 66.91  | 80.78   | 83.66   | 77.11   |
| I\(_4\)   | 60.96   | 66.57   | 78.64   | 68.72   | 59.86  | 65.13   | 76.55   | 67.18   | 60.41  | 65.85   | 77.59   | 67.95   |
| Mean      | 74.44   | 85.66   | 99.15   | 86.41   | 71.18  | 87.90   | 99.12   | 86.07   | 72.81  | 86.78   | 99.14   | 86.24   |
| CD\(_{0.05}\) |        |         |         |         |       |         |         |         |       |         |         |         |
| I         | 5.23    |         | 3.43    |         |       | 3.55    |         |         |       |         |         |         |
| N         | 4.53    |         | 2.97    |         |       | 3.08    |         |         |       |         |         |         |
| I\(_x\)N  | 9.06    |         | 5.94    |         |       | 6.15    |         |         |       |         |         |         |

I\(_1\): (1.2 IW/CPE ratio), I\(_2\): (1.0 IW/CPE ratio), I\(_3\): (0.8 IW/CPE ratio), I\(_4\): (0.6 IW/CPE ratio)
N\(_1\): 75 % of recommended dose of N, N\(_2\): Recommended dose of N, N\(_3\): 125 % of recommended dose of N

Table 6: Effect of irrigation and N levels on total P uptake (kg ha\(^{-1}\)) in onion

| Treatment | 2015-16 | 2016-17 | Pooled |
|-----------|---------|---------|--------|
|           | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  |
| I\(_1\)   | 19.04   | 20.99   | 24.91   | 21.65   | 17.24  | 20.29   | 23.84   | 20.46   | 18.14  | 20.64   | 24.37   | 21.05   |
| I\(_2\)   | 15.77   | 18.15   | 22.52   | 18.81   | 15.47  | 18.31   | 21.46   | 18.42   | 15.62  | 18.23   | 21.99   | 18.61   |
| I\(_3\)   | 13.83   | 15.47   | 17.03   | 14.79   | 13.67  | 16.69   | 17.95   | 16.10   | 13.75  | 16.08   | 16.51   | 15.45   |
| I\(_4\)   | 10.34   | 11.59   | 14.95   | 12.29   | 12.75  | 13.63   | 14.34   | 13.57   | 11.54  | 12.61   | 14.65   | 12.93   |
| Mean      | 14.74   | 16.55   | 19.36   | 16.89   | 14.78  | 17.23   | 19.40   | 17.14   | 14.76  | 16.89   | 19.38   | 17.01   |
| CD\(_{0.05}\) |        |         |         |         |       |         |         |         |       |         |         |         |
| I         | 1.77    |         | 1.68    |         |       | 1.27    |         |         |       |         |         |         |
| N         | 1.53    |         | 1.46    |         |       | 1.09    |         |         |       |         |         |         |
| I\(_x\)N  | NS      |         | NS      |         |       | NS      |         |         |       |         |         |         |

I\(_1\): (1.2 IW/CPE ratio), I\(_2\): (1.0 IW/CPE ratio), I\(_3\): (0.8 IW/CPE ratio), I\(_4\): (0.6 IW/CPE ratio)
N\(_1\): 75 % of recommended dose of N, N\(_2\): Recommended dose of N, N\(_3\): 125 % of recommended dose of N

Table 7: Effect of irrigation and N levels on total K uptake (kg ha\(^{-1}\)) in onion

| Treatment | 2015-16 | 2016-17 | Pooled |
|-----------|---------|---------|--------|
|           | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  | N       | N\(_1\) | N\(_2\) | N\(_3\) | Mean  |
| I\(_1\)   | 90.8    | 102.3   | 120.5   | 104.5   | 88.5   | 104.2   | 126.7   | 106.5   | 89.7   | 103.3   | 123.6   | 105.5   |
| I\(_2\)   | 75.7    | 86.3    | 107.6   | 89.9    | 78.5   | 99.1    | 107.7   | 95.1    | 77.1   | 92.7    | 107.7   | 92.5    |
| I\(_3\)   | 67.7    | 75.6    | 78.1    | 73.8    | 68.3   | 84.5    | 90.7    | 81.2    | 68.0   | 80.1    | 84.5    | 77.5    |
| I\(_4\)   | 58.8    | 63.1    | 76.0    | 66.0    | 60.1   | 66.1    | 78.1    | 68.1    | 59.5   | 64.6    | 77.1    | 67.1    |
| Mean      | 73.2    | 81.8    | 95.6    | 83.6    | 73.9   | 88.5    | 100.8   | 87.7    | 73.6   | 85.2    | 98.2    | 85.7    |
| CD\(_{0.05}\) |        |         |         |         |       |         |         |         |       |         |         |         |
| I         | 5.2     |         | 3.8     |         |       | 3.7     |         |         |       |         |         |         |
| N         | 4.5     |         | 3.3     |         |       | 3.2     |         |         |       |         |         |         |
| I\(_x\)N  | 9.1     |         | 6.6     |         |       | 6.4     |         |         |       |         |         |         |

I\(_1\): (1.2 IW/CPE ratio), I\(_2\): (1.0 IW/CPE ratio), I\(_3\): (0.8 IW/CPE ratio), I\(_4\): (0.6 IW/CPE ratio)
N\(_1\): 75 % of recommended dose of N, N\(_2\): Recommended dose of N, N\(_3\): 125 % of recommended dose of N
**Table 8** Effect of irrigation and N levels on bulb yield (q ha⁻¹)

| Treatments | 2015-16 | 2016-17 | Pooled |
|------------|---------|---------|--------|
|            | N       | N₁      | N₂      | N₃      | Mean  | N₁      | N₂      | N₃      | Mean  | N₁   | N₂   | N₃   | Mean  |
| I₁         | 370.0   | 390.7   | 462.7   | 407.8   | 354.7  | 406.0   | 471.3   | 410.7   | 362.3  | 398.3 | 467.0 | 409.2 |
| I₂         | 346.7   | 364.0   | 423.7   | 378.1   | 350.7  | 373.3   | 447.3   | 390.4   | 348.7  | 368.7 | 435.5 | 384.3 |
| I₃         | 324.7   | 340.0   | 381.3   | 348.7   | 320.0  | 357.3   | 389.3   | 355.6   | 322.3  | 348.7 | 385.3 | 352.1 |
| I₄         | 306.0   | 316.7   | 358.3   | 327.0   | 290.7  | 305.3   | 327.3   | 307.8   | 303.7  | 305.7 | 342.8 | 317.4 |
| Mean       | 336.8   | 352.8   | 406.5   | 365.4   | 329.0  | 360.5   | 408.8   | 366.1   | 334.3  | 355.3 | 407.7 | 365.8 |

| CD(0.05)   |         |         |         |         |        |         |         |         |        |      |      |      |      |
| I          | 10.2    |         |         |         |        | 13.5    |         |         |        |      |      |      | 7.1   |
| N          | 8.9     |         |         |         |        | 11.7    |         |         |        |      |      |      | 6.2   |
| IxN        | 17.7    |         |         |         |        | 23.3    |         |         |        |      |      |      | 12.4  |

I₁: (1.2 IW/CPE ratio), I₂: (1.0 IW/CPE ratio), I₃: (0.8 IW/CPE ratio), I₄: (0.6 IW/CPE ratio)
N₁: 75 % of recommended dose of N, N₂: Recommended dose of N, N₃: 125 % of recommended dose of N

**Table 9** Effect of irrigation levels on water requirement and water use efficiency

| Treatments | Irrigation applied (cm) | Effective rainfall (cm) | Profile water use (cm) | Total water requirement (IWA+ER+profile water use) (cm) | TWR (Average) (cm) | WUE kg ha⁻¹ mm⁻¹ | WUE (kg ha⁻¹ mm⁻¹) (Average) |
|------------|------------------------|-------------------------|------------------------|-------------------------------------------------------|-------------------|------------------|---------------------|
|            | 2016       | 2017       | 2016      | 2017      | 2016     | 2017     | 2016     | 2017     | 2016   | 2017   |       | |
| I₁         | 27.5       | 31.5       | 5.96      | 7.26      | 1.96     | 0.38     | 35.42    | 39.14    | 37.28  | 115.1  | 104.9 | 110.0 |
| I₂         | 23.5       | 27.5       | 8.84      | 8.26      | 2.11     | 1.53     | 34.45    | 37.29    | 35.87  | 109.7  | 104.6 | 107.0 |
| I₃         | 19.5       | 23.5       | 11.5      | 9.26      | 3.40     | 3.49     | 34.40    | 36.25    | 35.32  | 101.3  | 98.0  | 99.7  |
| I₄         | 15.5       | 19.5       | 13.8      | 9.36      | 4.20     | 4.24     | 33.50    | 31.10    | 32.30  | 97.6   | 92.0  | 94.8  |

*Figures in parentheses are the number of irrigations applied

**Table 10** Effect of irrigation and N levels on water use efficiency (kg ha⁻¹ mm⁻¹) in onion

| Treatment | 2015-16 | 2016-17 | Pooled |
|-----------|---------|---------|--------|
|           | N       | N₁      | N₂      | N₃      | Mean  | N₁      | N₂      | N₃      | Mean  | N₁   | N₂   | N₃   | Mean  |
| I₁        | 104.4   | 110.3   | 130.6   | 115.1   | 90.6   | 103.7   | 120.4   | 104.9   | 97.5   | 107.0 | 125.5 | 110.0 |
| I₂        | 100.6   | 105.6   | 122.9   | 109.7   | 94.0   | 100.1   | 119.9   | 104.6   | 97.3   | 102.8 | 121.4 | 107.1 |
| I₃        | 94.3    | 98.8    | 110.8   | 101.3   | 88.2   | 98.5    | 117.3   | 101.2   | 91.2   | 98.6  | 114.0 | 101.2 |
| I₄        | 91.3    | 94.5    | 106.9   | 97.5    | 93.4   | 98.1    | 110.2   | 100.5   | 92.3   | 96.3  | 108.5 | 99.0  |
| Mean      | 97.6    | 102.3   | 117.8   | 105.9   | 91.5   | 100.1   | 116.9   | 102.8   | 94.5   | 101.1 | 117.3 | 104.3 |

| CD(0.05) |         |         |         |         |        |         |         |         |        |      |      |      |      |
| I         | 5.2     |         |         |         |        | 3.8     |         |         |        | 3.7   |      |      |      |
| N         | 4.5     |         |         |         |        | 3.3     |         |         |        | 3.2   |      |      |      |
| IxN       | 9.1     |         |         |         |        | 6.6     |         |         |        | 6.4   |      |      |      |

I₁: (1.2 IW/CPE ratio), I₂: (1.0 IW/CPE ratio), I₃: (0.8 IW/CPE ratio), I₄: (0.6 IW/CPE ratio)
N₁: 75 % of recommended dose of N, N₂: Recommended dose of N, N₃: 125 % of recommended dose of N
The interaction effect of irrigation and N levels on yield of onion was found to be significant (Table 8). The onion yield increased with higher frequency of irrigation and increasing N levels.

The response of yield to high amounts of water and N application could be attributed to the favorable effect on the availability of nutrients to the plant roots, which improves the growth of the crop. Significant increase in yield due to higher N application might also be due to increased photosynthesis as N is a major constituent of chlorophyll molecule which plays an important role in photosynthesis. Increased photosynthesis results in accumulation of carbohydrates in the bulb and ultimately enhanced the plant growth and hence the yield [Neerja et al., (1999) in onion and Kemal (2014) in shallot].

These results further get support from the findings of Sanchez (2000) in lettuce, Goudra and Rokhade (2001) in cabbage, Rahman (2007) in tomato and Bozkurt et al., (2011) in cauliflower. Better expression of growth and yield under higher quantum of irrigation and N were also reported by Singh et al., (2010) in potato because of complimentary effect of nutrient availabilities to the plants.

**Total water requirement**

The crop water requirement increased with frequency of irrigations (Table 9). The highest and almost equal water requirement during 2015-16 being 35.42 cm and 34.45 cm was recorded under I₁ and I₂ levels, respectively and lowest under I₄ (33.50 cm). During second year, water requirement was comparatively higher but the trend was similar to first year of study and highest water requirement (39.14 and 37.29 cm) was recorded under I₁ and I₂ and lowest (31.10 cm) under I₄ irrigation level. On the basis of average of two years, highest (37.28 cm) total water requirement was noted under I₁ irrigation level which was very closely followed by I₂ (35.87 cm) and I₃ (35.32 cm) and lowest (32.30 cm) under I₄ level.

**Water use efficiency (WUE)**

It is necessary to apply irrigation judiciously to maximize crop growth and WUE. Under irrigation levels (Table 10) highest WUE (115.1 and 104.9 kg ha⁻¹ mm⁻¹) was recorded under I₁ followed by I₂ (109.7 and 104.6 kg ha⁻¹ mm⁻¹), I₃ (101.3 and 101.2 kg ha⁻¹ mm⁻¹) and lowest (97.5 and 100.5 kg ha⁻¹ mm⁻¹) was recorded under I₄ level, during the year 2015-16 and 2016-17, respectively. Among N levels, highest WUE was noticed under N₃ (117.8 and 116.9 kg ha⁻¹ mm⁻¹) and lowest under N₁ (97.6 and 91.5 kg ha⁻¹ mm⁻¹) during the years 2015-16 and 2016-17. Among the treatment combinations, highest WUE was recorded under I₁N₃ (130.6 and 120.4 kg ha⁻¹ mm⁻¹) followed by I₂N₃ (122.9 and 119.9 kg ha⁻¹ mm⁻¹) and lowest under I₄N₁ (91.3 and 93.4 kg ha⁻¹ mm⁻¹) during both the years of study. As the WUE is the ratio of yield to that of water applied, comparatively higher yield of onion under I₁ and I₂ (Table 8) gave higher WUE and the increase could be attributed to favourable effect of moisture regimes. Many earlier researchers have also reported higher WUE with the increase in irrigation water applied in groundnut, onion, green gram and cabbage (Taha and Gulati, 2001; Bandyopadhyay et al., 2003; Idnani and Gautam, 2008; Nyatuame et al., 2013).

In conclusion, efficient irrigation level is necessary for maintaining optimum soil moisture regimes for providing favourable environment for nutrient availabilities and their uptake. The study has led to a conclusion that for maximizing growth and productivity of onion in Himachal Pradesh, the integration
of irrigation level 1.0 IW/CPE with an application of 125 per cent of recommended dose of N (125 kg ha\(^{-1}\)) is best as it gave higher water use efficiency (109.7 and 104.6 kg ha\(^{-1}\) mm\(^{-1}\)) with total water requirement of (34.40 and 36.25 cm) during both the years.

References

Adetunji I A. 1990. Effect of mulches and irrigation on growth and yield of lettuce in semi arid region. *Biotronics* 19: 93-98.

Alam MS, Mallik SA and Costa DJ. 2010. Effect of irrigation on growth and yield of (*Daucus carota* ssp. *sativus*) carrot in hill valley. *Bangladesh Journal of Agricultural Research* 35: 323-329.

Al-Solaimani S G and Basahi J M. 2002. Effect of watering interval and N fertilization on cabbage yield and uptake in Makkah region. *Journal of Agricultural Sciences Mansoura University* 27(2): 1315-1322.

Bandyopadhyay PK and Mallick S. 2003. Actual evapotranspiration and crop coefficients of onion (*Allium cepa* L.) under varying soil moisture levels in the humid tropics of India. *Tropical Agriculture* 80: 27-31.

Bozkurt S and Mansuroglu GS. 2011. Lettuce yield responses to different drip irrigation levels under open field condition. *Journal of Cell and Plant Science* 2: 12-18.

Bungard RA, Wingler A, Morton JD and Andrews M. 1999. Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in *Climatis vitalba*. *Plant Cell Environment* 22: 859-866.

Chapman H D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian Journal of Horticulture* 21:97-199.

Evett S R, Schwartz R, Mazahrih N T, Jitan M A and Shaqir I M. 2011. Soil water sensors for irrigation scheduling: Can they deliver a management allowed depletion, (ed.) U. Yermiyahu, A Ben-Gal, A Dag 888: 231-238.

Gill G, Humphreys E, Kukal S, and Walia U. 2011. Effect of water management on dry seeded and puddled transplanted rice. Part 1: Crop performance. *Field Crops Research* 120(1):112-122.

Goudra KHB and Rokhade AK. 2001. Effect of irrigation schedules and methods on growth and yield of cabbage. *Journal of Agricultural Science* 14: 721-723.

Guimera J, Mafra O, Candela L and Serrano L. 1995. Nitrate leaching and strawberry production under drip irrigation management. *Agriculture Ecosystem and Environment* 56 (2): 121-135.

Gulsum SM, Sefer B, Melisa K and Selda T. 2010. The effects of nitrogen forms and rates under different irrigation levels on yield and plant growth of lettuce. *Journal of Cell and Plant Science* 1: 33-40.

Hara M and Saha R R. 2000. Effects of different soil moisture regimes on growth, water use and nitrogen nutrition of potted tomato seedling. *Japanese Journal of Tropical Agriculture* 44 (1):1-11.

Hegde DM and Srinivas K.1989. Studies on irrigation and nitrogen requirement of tomato. *Indian Journal of Agronomy* 34: 157-162.

Idnani LK and Gautam HK. 2008. Water economization in summer green gram (*Vigna radiata* var *radiata*) as influenced by irrigation regimes and configurations. *Indian Journal of Agricultural Sciences* 78: 214-219.

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 Agriculture Research* 8(37): 4637-4643.

Kuchenbuch RO, Ingram KT and Buczko U. 2006. Effects of decreasing soil water content on seminal and lateral roots of young maize plants. *Journal of Plant Nutrition and Soil Science* 169: 814-848.
tomato production. Ph.D. Thesis, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.).

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

Lapeyne F, Rangers J and Vanelles D. 1991. Phosphate solubilising activity of ectomycorrhiza fungi in vitro. Canadian Journal of Botany 69: 342-346.

Lingaiah D, Katti G S and Shaik M. 2005. Influence of drip irrigation on crop growth, yield and water use efficiency in cabbage (Brassica oleracea). International Journal of Agricultural Sciences 1(1): 110-111.

Lorenz O A and Maynard D N. 1980. Knoff’s Handbook for Vegetable Growers. 2nd ed. Wiley-Inter Science Publication, New York. 582.

Neeraja G, Reddy KM, Reddy IP, Reddy YN. 1999. Effect of irrigation and nitrogen on growth, yield and yield attributes of rabi onion (Allium cepa L.) in Andhra Pradesh. Vegetable Sciences 26: 64-68.

Nyatuame M, Ampia F, Owusu GV and Ibrahim BM. 2013. Irrigation scheduling and water use efficiency on cabbage yield. International of Journal of Agronomy and Agricultural Research 3: 29-35.

Patel GN, Patel PT and Patel PH. 2008. Yield, water use efficiency and moisture extraction pattern of summer groundnut as influenced by irrigation schedules, sulphur levels and sources. Journal of Agriculture Research 6: 1-4.

Rahman MJ, Mondol MAI, Rahman MN, Begum RA and Alam MK. 2007. Effect of irrigation and nitrogen on tomato yield in the grey terrace soil of Bangladesh. Journal of Soil Nature 1: 1-4.

Ramana Murthy K V and Reddy D S. 2013. Effect of irrigation and weed management practices on nutrient uptake and economics of production of aerobic rice. Journal of Agriculture and Veterinary Science 3(1): 15-21.

Rathore AC and Singh JN. 2009. Optimization of nitrogen application and irrigation for improved growth and spike production of tuberose (Polianthus tuberosum L.). Indian Journal of Soil Conservation 37: 45-49.

Sanchez CHA. 2000. Response of lettuce to water and nitrogen on sand and the potential for leaching of nitrate-N. Horticulture Science 35: 73-75.

Taha M and Gulati JML. 2001. Influence of irrigation on yield and moisture utilization of groundnut (Arachis hypogaea L.). Indian Journal of Agronomy 46: 523-527.

Tolga E, Levent A, Yesim E, Serdar P, Murat D, Hakan O and Huseyin TG. 2010. Yield and quality response of drip irrigated broccoli (Brassica oleracea L. var. italica) under different irrigation regimes, nitrogen applications and cultivation periods. Agricultural Water Management 97: 681–688.

How to cite this article:

Samir Bhatti, J.C. Sharma and Ridham Kakar. 2019. Effect of Irrigation and Nitrogen Levels on Nutrient Uptake, Water Use Efficiency and Productivity of Onion (Allium cepa L.) in Himachal Pradesh. Int.J.Curr.Microbiol.App.Sci. 8(02): 398-408.
doi: https://doi.org/10.20546/ijcmas.2019.802.045