Indian Journal of Ecology (2022) 49(6): 2088-2092
DOI: https://doi.org/10.55362/IJE/2022/3790

Manuscript Number: 3790
NAAS Rating: 5.79

Effect of Varying Irrigation and Fertigation Levels on Soil Water Dynamics and Water Use Efficiency of Potato in Wet Temperate Zone of Himachal Pradesh

Shakshi Mankotia, Sanjay K. Sharma and Manpreet Singh Brar[1]

Department of Soil Science, CSK Himachal Pradesh Agricultural University, Palampur-176 062, India
[1]Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: mankotiashakshi94@gmail.com

Abstract: The present study was conducted at the experimental farm of Department of Soil Science, CSK HPKV, Palampur to study the effect of varying irrigation and fertigation levels on soil moisture content, relative leaf water content and water use efficiency of Potato. The experiment comprised of ten treatments, each replicated three times, including three drip irrigation levels viz., 0.4 PE, 0.6 PE and 0.8 PE, three fertigation levels viz., 50% RDF, 75% RDF and 100% RDF and Recommended Practice. Soil moisture content and relative leaf water content (RLWC) were significantly higher at irrigation level of 0.8 PE as compared to Recommended Practice. The WUE and Irrigation water use efficiency (IWUE) decreased with increase in the irrigation levels whereas fertigation levels increased it. Both WUE and IWUE were significantly highest at irrigation level of 0.4 PE followed by 0.6 PE and minimum at irrigation level of 0.8 PE over recommended practice.

Keywords: Drip irrigation and fertigation, RLWC, WUE, Soil moisture content, Potato

Potato (*Solanum tuberosum* L.) is an herbaceous plant with sparse and shallow rooting system and requires light and frequent irrigations throughout period of crop growth. It is very sensitive to the changes in the soil moisture content and the decrease in water content, leading to a significant reduction in tubers quantity as well as quality. Many factors affected potato production, including cultivars, weather conditions, planting date, nutrition and irrigation. The water requirement of potato vary under different growth stages. Tubers initiation and tubers bulking stages are the most sensitive growth stages of potato to water deficit. During water deficit conditions, many physiological and biochemical processes are disturbed. Continuous water supply is generally recommended from tuber initiation to maturity stage (Khalel 2015). Improved irrigation methods like drip method can save water without compromising potato yield or quality. As conventional method of irrigation results in losses of nutrients through leaching, surface runoff and also create adverse condition for plant growth like water logging to some extent. Efficient irrigation techniques are therefore needed for maximizing the efficiency of water and applied nutrients. Drip irrigation is the most efficient method of water utilization for the crop growth which helps to achieve considerable amount of water saving with high WUE compared to surface irrigation method, where irrigation efficiency is low due to losses in water distribution on the field. So, scheduling water application is very critical to make the most efficient use of drip irrigation system, as excessive irrigation reduces yield, while inadequate irrigation causes water stress and reduces production. Drip irrigation method has ability to apply small but frequent irrigation, and has found to be superior over flood method in respect of water saving, yield, quality of produce and WUE (Kassu et al 2017).

Moreover, the drip fertigation systems offer opportunity to apply appropriate amount of nutrients and chemicals along with water, which reduces leaching losses and enhances water content in soil as well as IWUE. Drip irrigation can save water use by 30 to 70 per cent and raises crop yields by 20 to 90 per cent depending on soil, climatic and crop characteristics. It mainly controls the vegetative growth and improving the IWUE (Ayas, 2021). The relative leaf water content (RLWC) is an important indicator of water status in plants as it reflects the balance between water supply to the leaf tissue and transpiration rate (Lugojan and Ciulca, 2011). Research on drip fertigation conducted so far in India and abroad has shown that this method leads not only the appreciable saving of water as well as fertilizer but also returns in achieving higher crop yields as compared to flood irrigation method. For this, advanced irrigation and fertilization techniques are required. Therefore, the present investigation is executed to study the effect of different irrigation and fertigation levels on soil water content, RLWC and WUE of potato in wet temperate zone of Himachal Pradesh.

MATERIAL AND METHODS

The present study was conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental farm is situated at 32° 6' N latitude and 76° 3' E longitude at an altitude of about 1290 m above mean sea level. The site lies in the Palam valley of Kangra district representing mid hill wet temperate zone (Zone 2.2) of Himachal Pradesh. Taxonomically, the soils of study area fall under order Alfisol and sub-group Typic Hapludalf. These soils have originated from rocks like slates, phyllites, quartzites, schists and gneisses. The field experiment on potato (cv. Kufri Jyoti) was laid out in randomized block design with ten treatments, each replicated three times. Ten treatments comprised of three drip irrigation levels viz., 0.4 PE, 0.6 PE and 0.8 PE corresponding to 40, 60 and 80 per cent of cumulative pan evaporation, respectively, three fertigation levels viz., 50% RDF, 75% RDF and 100% RDF equivalent to 50, 75 and 100 per cent of recommended dose of NPK, respectively and RP i.e. recommended practice (recommended dose of fertilizers was applied through conventional methods and 6 flood irrigations of 50 mm each). The recommended dose of fertilizers (RDF) for potato was N, P_2O_5 and K_2O were 120, 80 and 60 kg/ha, respectively. The irrigations were applied through online drip system on alternate days for each treatment. Fertigation was done as per treatments using urea and water soluble fertilizers 17:44:00 and 00:00:50 in calculated proportions. Fertigation was started after complete emergence of the crop. Fertigation with 17:44:00 and 00:00:50 was completed in 5 splits whereas, urea was applied in 10 splits. In the last treatment i.e. RP, recommended dose of fertilizers was applied through urea, single super phosphate and muriate of potash. Half of the nitrogen dose (60 kg/ha N) and full dose of phosphorus and potassium was applied in the RP treatment at the time of sowing. The remaining dose of nitrogen in this treatment was applied at the time of earthing up. Six irrigations @ 50 mm water per irrigation were applied during the crop period. Soil samples were collected periodically at an interval of 15 days after the start of drip irrigation from each plot from a depth of 0-0.15 m and 0.15-0.30 m for determination of moisture content in soil.

Relative leaf water content: The relative leaf water content (RLWC) was determined at tuber initiation and bulking stages at 7:00 am and 12:00 noon. It was computed from the fresh weight, turgid weight and oven dry weight according to the method given by Weatherly (1950).

$$\text{RLWC} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fully turgid weight} - \text{Oven dry weight}} \times 100$$

Water use efficiency: The tuber yield obtained for each treatment was divided by the quantity of water used (irrigation water + rainfall) for the respective treatments by this method. Water use efficiency was worked out and expressed in kg ha-mm^{-1} of water used.

$$\text{WUE} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Total water use (ha-mm)}}$$

Likewise, irrigation water use efficiency was worked out as:

$$\text{IWUE} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Irrigation water use (ha-mm)}}$$

RESULTS AND DISCUSSION

Soil moisture studies during crop growth: The soil moisture contents determined at 15 days interval throughout the growth period (Fig. 1 and 2). The soil moisture contents determined on dry weight basis at first sampling after initiation of the crop on February 17, 2016 were 22.6 and 23.9 per cent in 0.4 PE, 22.7 and 23.5 per cent in 0.6 PE and 22.5 and 23.8 per cent in 0.8 PE at 0-0.15 and 0.15-0.30 m depths, respectively. The soil water contents were almost similar under all the irrigation levels. The contents in the sub surface layer were found to be higher in comparison to the top layer. The moisture contents determined after 15 days of first sampling that is on 3-3-2016 were higher in comparison to previous sampling owing to the effect of drip irrigations. The highest moisture content of 25.6 per cent was with irrigation level of 0.8 PE whereas, minimum (23.8 %) was in 0.4 PE followed by 0.6 PE (24.8 %) in 0-0.15 m depth. Like the previous sampling, the soil moisture contents in 0.15-0.30 m depth were higher in comparison to the top soil and varied between 26.3 per cent (0.4 PE) to 27.2 per cent (0.8 PE). The moisture content recorded on March 19, 2016 did not show much difference among various levels as it varied from 28.5 per cent at 0.4 PE to 28.9 per cent at 0.8 PE. Almost similar contents were recorded in the sub surface layer of 0.15-0.30 m depth also as these varied from 28.0 per cent in 0.4 PE to 29.1 per cent in 0.8 PE.

This was probably due to the significant amount of water received during the preceding week through rainfall which might have neutralized the effect of irrigation levels. The moisture contents in samples collected on 2-4-2016 varied from 21.6 per cent at 0.4 PE to 24.6 per cent at 0.8 PE in surface soil whereas, in the 0.15-0.30 m soil depth these varied from 24.5 per cent in 0.4 PE to 25.3 per cent in 0.8 PE. The moisture content at the next sampling on 17-4-2016 varied from 22.5 per cent at 0.4 PE to 23.8 per cent at 0.8 PE. Little higher moisture contents were recorded in the sub surface layer of 0.15-0.3 m depth also as these varied from 23.5 per cent in 0.4 PE to 24.7 per cent in 0.8 PE.

The moisture contents in top soil (0-0.15 m) recorded on May 2, 2016 varied from 21.7 per cent at 0.4 PE to 23.6 per cent at 0.8 PE and from 22.3 per cent at 0.4 PE to 24.1 per cent at 0.8 PE in samples collected on 17-5-2016. Likewise, the moisture contents in 0.15-0.30 m soil depth on 2-5-2016 and 17-5-2016 varied between 24.6 and 23.8 per cent, respectively at 0.4 PE to 25.4 and 24.7 per cent, respectively at 0.8 PE. The moisture contents at the last sampling on June 1, 2016 were comparatively higher in comparison to the previous sampling and similar trend was observed with respect to the drip irrigation levels. The moisture contents in the lower layer were higher in comparison to the surface layer. Soil moisture contents under recommended practice were almost equal or higher than recorded under 0.8 PE at all the sampling stages except the last where these were lower in both the soil depths. In general, higher moisture contents were observed at irrigation level of 0.8 PE in comparison to the other levels due to higher amount of water applied in this treatment. The soil water content changed more under the influence of irrigation levels in the upper soil layer than in the lower layer. Similar results have been reported by Mokh et al (2014), Kapoor (2016) and Abedin et al (2017).

Relative Leaf Water Content (RLWC)

Tuber initiation stage: Application of different levels of irrigation water influenced the relative leaf water contents significantly at this stage (Table 1). Application of water @ 0.8 PE recorded significantly higher RLWC at tuber initiation

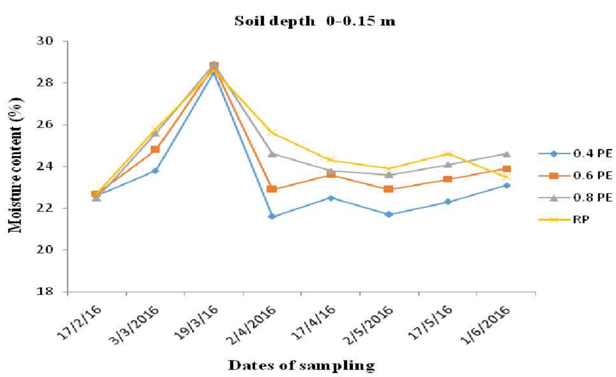

Fig. 1. Effect of irrigation levels on soil water content during crop growth at 15 days interval in 0-0.15 m soil depth

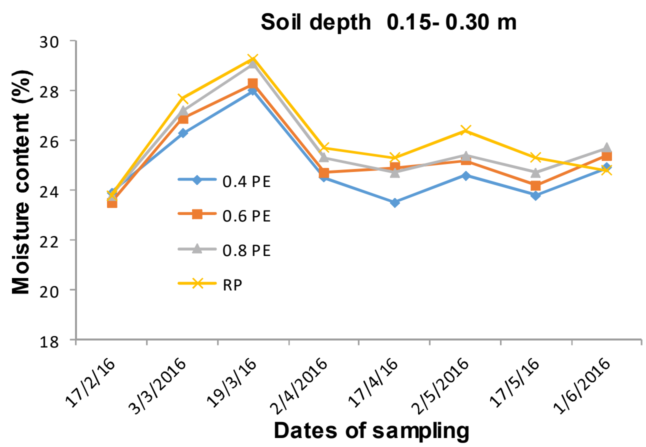

Fig. 2. Effect of irrigation levels on soil water content during crop growth at 15 days interval in 0.15-0.30 m soil depth

Table 1. Effect of drip irrigation and fertigation levels on relative leaf water content (RLWC) at tuber initiation and bulking stage

Treatment	RLWC (%)			
	Tuber initiation stage		Bulking stage	
	7 am	12 pm	7 am	12 pm
Irrigation level				
0.4 PE	80.2	70.5	80.6	71.5
0.6 PE	81.2	72.4	81.5	72.7
0.8 PE	81.7	74.4	82.0	74.7
CD (P=0.05)	1.2	2.7	1.0	2.4
Fertigation level				
50 % RDF	80.8	71.8	81.2	72.5
75 % RDF	81.1	72.2	81.4	72.5
100 % RDF	81.2	73.3	81.5	73.9
CD (P=0.05)	NS	NS	NS	NS
Recommended practices (RP) vs others				
RP	82.6	76.1	82.5	76.8
Others	81.0	72.4	81.4	73.0
CD (P=0.05)	1.5	3.5	NS	3.1

stage (81.7 % and 74.4 %, at 7 am and 12 pm, respectively) in comparison to 0.4 PE (80.2 % and 70.5 %, at 7 am and 12 pm, respectively). However, no significant differences were observed in RLWC between irrigation levels of 0.4 PE and 0.6 PE. Likewise, RLWC at 0.6 PE was statistically at par with that observed at 0.8 PE. The higher relative leaf water content under irrigation level of 0.8 PE in comparison to 0.4 PE might be due to considerably higher amount of water applied under this level in comparison to later. Almost similar findings in different crops have been reported by Thakur (2015), Dorota et al (2016) and Kapoor (2016). RLWC under recommended practice was significantly higher (82.6 per cent and 76.1 per cent, at 7 am and 12 pm, respectively) in comparison to overall mean of others (81.0 per cent and 72.4 per cent, at 7 am and 12 pm, respectively) probably due to higher amount of water applied under recommended practice. Fertigation levels did not influence the relative leaf water content of potato plants significantly. The interaction between irrigation and fertigation was not significant.

Bulking stage: Application of different levels of irrigation water influenced the relative leaf water contents significantly at bulking stage also (Table 1). Similar trends with respect to the effect of irrigation and fertigation levels were observed in the RLWC at this stage as were observed during the tuber initiation stage. The RLWC contents of plants under drip irrigation levels of 0.4, 0.6 and 0.8 PE were 80.6, 81.5 and 82 per cent, respectively at 7.00 am and 71.5, 72.7 and 74.7 per cent, respectively at 12.00 pm. The higher RLWC values at 0.8 PE during bulking stage too might be ascribed to more availability of water to plants due to higher amount of irrigation water applied. The RLWC under recommended practice was statistically at par with overall mean of others at 7.00 am, though at 12 PM on same day, recommended practice recorded significantly higher RLWC (76.8 %) in comparison to overall mean of others (73 %). Fertigation levels did not influence the relative leaf water content of potato plants significantly. Also the interaction between irrigation and fertigation was not significant. Irrespective of irrigation or fertigation levels, during both the growth stages, RLWC contents recorded at 7.00 am were higher than recorded at 12.00 pm. However, no water stress was observed at any level of irrigation even at 12.00 pm as RLWC was more than 70 percent even at lower level of irrigation.

Water use efficiency (WUE): Water use efficiency at irrigation level of 0.4 PE was highest (38.4 kg/ha-mm) followed by 0.6 PE and minimum at irrigation level of 0.8 PE (33.5 kg/ha-mm) (Table 2). However, the difference in WUE was significant only between 0.4 PE and 0.8 PE. As regards the effect of fertigation levels, data revealed that WUE was significantly higher in 75 per cent recommended dose of fertilizers (39.3 kg/ha-mm) in comparison to fertigation level of 50 per cent recommended dose of NPK (32.2 kg/ha-mm) by about 22 per cent. However, 75 per cent recommended dose of fertilizer was statistically at par with 100 per cent recommended dose of fertilizers which recorded WUE of 37.6 kg ha-mm^{-1}. Similar results were reported by Ati et al (2012), Mokh et al (2014), Ghiyal et al (2016) and Kassu et al (2017). In recommended practice vs. others', WUE under others (36.4 kg/ha-mm) was significantly higher by about 37 per cent in comparison to the recommended practice (26.5 kg/ha-mm).

Table 2. Effect of drip irrigation and fertigation levels on WUE and IWUE

Treatments	WUE (kg/ha-mm)	IWUE (kg/ha-mm)
Irrigation level		
0.4 PE	38.4	137.6
0.6 PE	37.2	101.4
0.8 PE	33.5	76.8
CD (p=0.05)	4.0	12.9
Fertigation level		
50 % RDF	32.2	93.1
75 % RDF	39.3	113.5
100 % RDF	37.6	109.3
CD (p=0.05)	4.0	12.9
Recommended practices (RP) vs others		
RP	26.5	57.9
Others	36.4	105.3
CD (p=0.05)	5.2	16.7

Irrigation water use efficiency (IWUE): IWUE was significantly higher in 0.4 PE (137.6 kg/ha-mm) in comparison to 0.6 PE (101.4 kg/ha-mm) and 0.8 PE (76.8 kg/ha-mm) (Table 2). Among different fertigation levels, the IWUE was highest in 75 per cent recommended dose of fertilizers (113.5 kg/ha-mm) which was about 21.9 per cent higher than that obtained with 50 per cent recommended dose of fertilizers (93.1 kg/ha-mm). Increase in the fertigation level to 100 per cent of recommended fertilizers recorded IWUE of 109.2 kg/ha-mm, however, it was statistically at par with 75 per cent recommended dose of fertilizers. Similar results were reported by Badr et al (2012), Mokh et al (2014) and Elhania et al (2019). As regards the comparison of 'Recommended practice (RP)' vs. 'others', IWUE under overall mean of others (105.2 kg/ha-mm) had significantly higher irrigation water use efficiency in comparison to recommended practice (57.9 kg/ha-mm), the magnitude of difference being 47.3 kg/ha-mm (an increase of about 81.7 % over RP).

CONCLUSION

The study concluded that gravimetric moisture content varied in soil as per irrigation levels and comparatively higher moisture contents were observed in the sub-surface samples. The soil moisture contents under all the irrigation levels were close to the field capacity during the crop season. The RLWC at tuber initiation and bulking stages were significantly higher at irrigation level of 0.8 PE in comparison to 0.4 PE. However, there was no significant difference between 0.6 PE and 0.8 PE irrigation levels. RLWC under various fertigation levels were statistically at par. The WUE and IWUE decreased with increase in the irrigation levels. Both were highest at irrigation level of 0.4 PE and minimum at irrigation level of 0.8 PE. WUE and IWUE under drip irrigation were recorded an increase of about 37 and 81.7 per cent over recommended practice, respectively.

REFERENCES

Abedin TK, Mattar MA, Alazba AA and Ghobari HM 2017. Comparative effects of two water-saving irrigation techniques on soil water status, yield, and water-use efficiency in potato. *Scientia Horticulturae* **225**: 525-532.

Ati AS, Iyada AD and Najim SM 2012. Water use efficiency of potato under different irrigation methods and potassium fertilizer rates. *Annals of Agricultural Sciences* **57**(2): 99-103.

Ayas S 2021. Response of potato (*Solanum tuberosum* L.) under different levels of irrigation and fertigation through drip system. *Turkish Journal of Agriculture-Food Science and Technology* **9**(2): 433-445.

Badr MA, Tohamy WA and Zaghloul AM 2012. Yield and water use efficiency of potato grown under different irrigation and nitrogen levels in an Arid Region. *Agricultural Water Management* **110**: 9-15.

Dorota SK, Plich J, Danuta SZ, Jadwiga S and Waldemar M 2016. The effect of drought stress on the leaf relative water content and tuber yield of a half-sib family of 'Katahdin'-derived potato cultivars. *Breeding Science* **66**: 328-331.

Elhania S, Haddadia M, Edina C, Zantara S, Hamima A, Vanda V, Douaikc A, Zsofia B 2019. Effects of partial root-zone drying and deficit irrigation on yield, irrigation water-use efficiency and some potato (*Solanum tuberosum* L.) quality traits under glasshouse conditions. *Agricultural Water Management* **224**: 105-112.

Ghiyal V, Bhatia AK and Maan DS 2016. Efficient use of water and fertilizer through drip fertigation in potato (*Solanum tuberosum* L.) in Haryana. *Biosciences Biotechnology Research Asia* **13**(4): 2025-2030.

Kapoor R 2016. *Effect of drip irrigation on soil-plant water dynamics, nutrient use and productivity of capsicum and broccoli under varying NPK fertigation in an acid alfisol.* Ph.D. Dissertation, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Kassu T, Tilahun H, Yared D and Watanabe H 2017. Effect of irrigation regimes on yield and water use efficiencies of potato. *International Journal of Plant Production* **11**(3): 389-406.

Khalel AMS 2015. Effect of drip irrigation intervals and some antitranspirants on the water status, growth and yield of potato (*Solanum tuberosum* L.). *Journal of Agricultural Science and Technology* **5**: 15-23.

Lugojan C and Ciulca S 2011. Evaluation of relative water content in winter wheat. *Journal of Horticulture, Forestry and Biotechnology* **15**: 173-177.

Mokh FE, Nagaz K, Masmoudi MM and Mechlia NB 2014. Effects of surface and subsurface drip irrigation regimes with saline water on yield and water use efficiency of potato in arid conditions of Tunisia. *Journal of Agriculture and Environment for International Development* **108**(2): 227-246.

Thakur M 2015. *Standardization of drip based irrigation and fertigation schedule in cucumber grown under protected condition*. M.Sc. Dissertation, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Weatherley PE 1950. Studies in the relations of the cotton plants. I. The field measurement of water deficits in leaves. *New Phytology* **49**: 36-51.

Received 22 September, 2022; Accepted 27 November, 2022