



Effect of Different Irrigation Levels and Potato Hybrids on Yield and Nutrient Uptake of the Crop under Water Stress Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. Authors Akash, VPSP, VG helped in conceptualization, performed methodology, did investigation and prepared original draft of the manuscript. Author CV reviewed and edited the manuscript. Authors AKB, SK, DS reviewed and edited the final draft. All authors read and approved the final manuscript.

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ABSTRACT

As the scarcity of water increases, India will face the problem of decreasing annual freshwater use per capita. Healthy and sufficient crop and food production is essential for everyone due to the population increasing globally. Drought can result in severe productivity losses, especially for crops like the potato (*Solanum tuberosum*) that have shallow roots. In agriculture, it's critical to keep an eye on the soil, the climate, and the water supply for a crop. The study was carried out at the research farm of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University-

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Hisar, India during the *rabi* season of the year 2018-19. The field experiment was conducted in split plot design with four irrigation levels I_1 (irrigation at 20mm CPE (Cumulative Pan Evaporimeter)), I_2 (irrigation at 25mm CPE), I_3 (irrigation at 30mm CPE) and I_4 (irrigation at 30mm CPE + 5 t/ha grass mulch) and five potato hybrids V_1 (P-21), V_2 (P-32), V_3 (P-37), V_4 (P-38), V_5 (Kufri Bahar) under two different crops at 60 and 75 days. The results revealed that parameters i.e., number of leaves, total tuber yield, and nitrogen uptake by crop were higher in both 60 and 75 days of crops under irrigation level 20 mm CPE (I_1) and hybrid P-38 but in water stress condition I_3 gives a better yield than other irrigation levels with hybrid -38. The present study opens up new doors to the farmers and researchers for sustainable production of potatoes.

Keywords: Water stress; potato hybrids; nutrient uptake; specific gravity; CPE.

1. INTRODUCTION

“Major obstacles to crop productivity may result from abiotic stressors. Due to their ability to reduce the average yield of most crops by 50–70%, abiotic stressors like heat, salinity, and water shortage are the primary causes of crop loss” Chai et al. [1]. Drought is one of the most influential abiotic stresses Seleiman et al. [2].

“Water scarcity is increasing as the population grows, which means that the need for fresh water is increasing as well. As a result of excessive water use and pollution over the last two decades. The annual freshwater supply per capita has decreased by more than 20%, around 1.2 billion people around the world are facing water scarcity due to their habitation in agricultural areas” Akash et al. [3]. “In the world, 92% of all freshwater is used for agricultural purposes, whether it's in the form of rivers, lakes, or underground aquifers” Zhai et al. [4]. “India will face a challenge in the coming decades to increase food production to feed a growing population while concurrently reducing annual freshwater consumption per capita. In many parts of the world, a lack of water is the main barrier to the production of potatoes. Both agronomists and potato grower farmers have high expectations for increased tuber yields per unit of water” Anonymous, [5].

“Potato (*Solanum tuberosum* L.) is a major crop grown in almost 150 countries globally. It is the world's fourth most cultivated crop, after wheat, rice, and maize. Potato is a member of the Solanaceae family and is one of the most important tuberous crops grown in India. It is native to South and Central America Saenkaew, [6]. This crop generates more edible energy and protein per unit area and time than many other crops and has an extraordinarily high yield (up to 25-30 t/ha). It contains a lot of carbohydrates, protein, and vitamin C. On the global stage, the

production of potatoes is 370 metric tonnes and 17.3 million cultivated hectares” Anonymous [7]. “India is the world's second-largest potato producer after China, with an average output of 24.4 t/ha. In 2021–22, the area and production of potatoes in India were 22.02 lakh hectares, yielding 533.87 lakh metric tons. In 2021-22, the area and production and productivity of potatoes in Haryana were 29.54 thousand hectares, 7.82 lakh metric tonnes, and 26.49 mt/ha, respectively,” Anonymous [5].

“Potato is considered a drought-sensitive crop and is subjected to yield loss due to drought stress. Also as climate change, the severity, frequency, and extent of droughts have been increasing worldwide. Potato's susceptibility to dryness has mostly been attributed to their weak roots. In the last few decades, several studies reported that the susceptibility of potatoes to drought depends on their genotype, stage of development, shape, and the length and severity of the drought stress. On the other hand, some researchers thought that the depth of the roots is the only main reason why potatoes are sensitive to dryness” Nasir and Toth, [8]. The biggest difficulty in restricting good potato yield to meet global demand is irrigation scheduling, which can be mitigated by effective water management and agronomic measures such as mulching.

“Nitrogen is a key element for improving crop growth, development, and quality of crop plants. It influences the yield mainly through leaf area expansion, crop development, crop quality, and susceptibility to lodging and can also affect the behavior of other elements” Devi et al. [9]. “Excessive or insufficient water availability has an impact on potato development and production” Fleisher et al. [10]. Mulching applications efficiently affect the plant's hydrothermal microenvironment; although, the effects of mulching on potato yield vary with field management and climate. Straw and plastic

mulching boosted potato output by 24.3% and 16.0%, respectively, while increasing water use efficiency (WUE) by 5.6% and 28.7%. There is still a large effect of mean growing season air temperature, water input, soil basic fertility, and fertilizer treatments on potato output [11].

“Potato acts as an indicator crop for potassium deficiency symptoms due to its higher potassium requirement. Potassium plays an important role in photosynthesis through enzyme activation, carbohydrate metabolism, water regulation, translocation of assimilates, and nitrogen uptake. Also, it has a role in physiological processes in plant respiration, transpiration, translocation of sugars and carbohydrates, and enzyme transformation. It enables the plant to synthesize the organic compounds linked with the absorption of nitrogen and its efficient utilization” Devi et. al. [9]. The result of this study would be worthwhile to find out the effect of different irrigation levels and potato hybrids on yield and nutrient uptake of the crop under water stress conditions.

2. MATERIALS AND METHODS

2.1 Experimental Design

The present study was carried out at Vegetable Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar during the rabi season, 2018-19. Hisar is situated at a latitude of 29° 10' N, longitude of 75° 46' E, and a height of 215.2 meters above mean sea level and falls in semi-arid and sub-tropical region with hot and dry summer and severe cold in winter. Before cultivation, soil samples were collected from the experimental site for chemical and physical analyses according to the different described methods. On October 25, 2018, various hybrids of potato tubers are being grown. By using a disc harrow and cultivator, the field was tilled three to five times. Each tilling was followed by planking to thoroughly aerate and level the soil. There were four main plot treatments which were taken as four different levels of irrigation, I₁: irrigation at 20mm Cumulative Pan Evaporimeter (CPE), I₂:irrigation at 25mm CPE, I₃:irrigation at 30mm CPE, and I₄: irrigation at 30mm CPE + 5 t/ha grass mulch at planting. Five sub-plot treatments of potato hybrids were used in this experiment, which are V1: AICRP-P-21, V2: AICRP-P-32, V3: AICRP-P-37, V4: AICRP-P-38, and V5: Kufri Bahar were laid out in a split block design with three replications keeping gross plot sizes of 4.2m x

3.4m and 3.0m x 3.0m, respectively. According to the designated irrigation schedules, irrigation was carried out in furrows. Three replications of each of the 60 and 75-day crop lengths were used in the split-plot design to fully analyze the experiment. By comparing results under the different irrigation schedules, we can quantify the best-suited potato hybrid for water stress on potato yield (q/ha), Nutrient (N P K) uptake by the crop, Specific gravity (gm/cm)³, and soil moisture observations at different stage from different treatments. All experimental hybrids were provided the same cultural practices *i.e.* fertilizer application, gap filling, earthing-up, weed management, haulm cutting, and plant protection measures during the whole period of investigation. The irrigation water was provided via a furrow irrigation system. We can quantify the best potato hybrid for water stress on potato yield and crop nutrient uptake by comparing results under various irrigation schedules.

2.2 Properties of the Soil Before the Experiment Conducted

The soil analysis was done before experimentation during 2018-2019 in which recorded available soil Nitrogen, Phosphorus, and Potassium were analyzed 146 kg/ha, 18.6 kg/ha, and 305.5 kg/ha, respectively. Soil pH was 7.6 and organic percentage was 0.48. Nitrogen availability is low in this field, phosphorus is medium, and potassium availability is adequate. Soil pH and organic carbon are suitable for potato crops in this soil. The recommended dose of fertilizer in potato crops is 150:50:100 (N, P & K) in the packaging practice of CCSHAU, Hisar.

The soil of the experimental field was analyzed for mechanical and chemical properties, and cropping history details are given in Table 1.

2.3 Growth and Parameters

2.3.1 Plant emergence

The count of plant emergence from each plot was recorded 30 days after planting and the percent plant emergence was worked out by the following formula:

Plant emergence (%) =

$$\frac{\text{Number of tubers sprouted per plot}}{\text{Total number of tubers planted per plot}} \times 100$$

Table 1. Initial fertility status of the soil (pH, Organic carbon, and available N, P and K)

Component	Value	Method
Clay (%)	12.6	International pipette method (Piper, 1996) Piper [12]
Silt (%)	15.5	International pipette method (Piper, 1996)
Sand (%)	71.9	International pipette method (Piper, 1996)
pH (1:2)	7.6	pH meter having glass electrode (Walkley and Black, 1934) Walkley and Black [13]
EC (dSm ⁻¹ at 25° C)	0.28	(Walkley and Black, 1934)
Organic carbon (%)	0.48	(Walkley and Black, 1934)
Available nitrogen (kg/ha)	146.0	Alkaline Permagnet method (Subbaiah and Asija, 1956) Subbaiah and Asija [14]
Available phosphorus (kg/ha)	18.6	Olsen et al. (1954) Olsen, [15]
Available potassium (kg/ha)	305.5	Ammonia acetate method [16]

2.3.2 Number of leaves per plant at 60 days after planting

For counting the number of leaves per plant, five random plants were selected and their leaves were counted at 60 days after planting separately. The average number of leaves per hill was worked out by dividing the number of leaves by the number of plants and used for the number of leaves 60 days after planting.

2.3.3 Total tuber yield (q/ha)

The weight of all tuber grades (A, B, C, and D grade tubers) in each net plot was added to determine the overall yield. Different grades of tubers' weights were measured per plant, and the values were later expressed in kilograms per square meter and quintals per hectare.

2.3.4 Nutrient (N, P, K) uptake by the crop

Nutrient uptake by the haulms was calculated by multiplying the dry weight of haulm with nutrient contents in the leaf sample divided by hundred and then expressed as kg/ha.

$$\text{Nutrients uptake by haulm} \left(\frac{\text{kg}}{\text{ha}} \right) =$$

$$\frac{\text{Nutrient in haulm (\%)} \times \text{Dry Weight of haulm (kg/ha)}}{100}$$

Nutrient uptake by the tuber was calculated by multiplying the nutrient contents in the tuber sample with the oven-dry weight of the tuber dividing them by hundred and expressed as kg per ha. Similarly, nutrient uptake by potato tuber was derived with the same formula.

$$\text{Nutrients uptake by tuber} \left(\frac{\text{kg}}{\text{ha}} \right) =$$

$$\frac{\text{Nutrient in tubers (\%)} \times \text{Dry weight of tuber (kg/ha)}}{100}$$

2.3.5 Specific gravity (g/cm)³

Specific gravity is the weight of the tuber in air compared to the weight of the same in water. It is a measurement of density and can be calculated as follows:.

$$\text{Specific Gravity SG} =$$

$$\frac{\text{Weight of tubers in air}}{(\text{weight in air}) - (\text{weight in water})}$$

2.3.6 Periodical soil moisture observations (at stolon formation, tuber initiation, and bulking stage) from 0-15 cm stage-wise from different treatments

The moisture content of the soil is calculated by subtracting the weight of the dry soil from the weight of the moist soil and then dividing it by the weight of the dry soil.

$$\text{Percent moisture content (MC)} =$$

$$\frac{\text{Weight of moist soil (M)} - \text{weight of dry soil (D)}}{\text{Weight of dry soil (D)}}$$

2.4 Data Analysis

The data recorded during the study for various parameters was statistically analyzed with the help of OPSTAT available at CCS HAU, Hisar, website.

3. RESULTS AND DISCUSSION

3.1 Plant emergence at 30 Days After Planting

Data revealed in Table 2 showed that plant emergence at 30 days after planting, the effect of

irrigation and hybrids was non-significant. The maximum plant emergence (97.2%) was recorded with Irrigation of 25 mm CPE. Among the various means of hybrids, maximum plant emergence (96.8%) was found with P-38. Interaction effects were found non-significant. The results of the present study are in agreement with the finding that plant emergence in potatoes ranged from 90 to 98 percent, however, there was no effect of fertilizer treatments on plant emergence Singh et al. [17]. Shiwani et al. [18] concluded that the adequate amount and frequency of irrigation stimulate the crop growth and development of most vegetable crops.

3.2 Number of Leaves Per Plant at 60 Days After Planting

Different irrigation levels and potato hybrids significantly affected the number of leaves per plant (Table 2). The number of leaves increased with the increase in irrigation levels. The maximum number of leaves (82.8) at 60 days after planting was recorded under an irrigation level of 20 mm CPE (I_1) while a minimum number of leaves was observed under irrigation 30 mm CPE. Among the potato hybrids, the maximum number of leaves (74.3) was registered in hybrid P-38 at 60 days after planting respectively.

Additionally, it has been noted that drought decreased the yield of tubers by 11% to 53% Lahlou et al. [19]. In every case, the dry mass of leaves was significantly reduced by drought stress. Only the early cultivars saw a reduction in tuber numbers; the later cultivars did not. In the first three weeks of tuber bulking, cultivars that kept their tuber growth rate better under water stress also kept their yields better. There was no discernible pattern or typical response of early versus later varieties to water stress.

3.3 Total Tuber Yield (q/ha)

The data provided in Table 2 showed that the irrigation schedules had a significant impact on the total tuber yield of the 60 and 75-day crops, which increased significantly as irrigation levels increased. The data clearly show that at irrigation level (I_1) 20 mm CPE, the total tuber yield was highest (329.6 and 457.8 q/ha). In both 60 and 75 days of the crop, hybrid P-38 had the highest total tuber yield among hybrids (290.1 and 393.8 q/ha).

“For 60 days of the crop, the interaction effect of hybrids at the same level of irrigation and irrigation at the same level of hybrid was found to be non-significant; however, for 75 days of the crop, it was found to be significant. According to research, frequent irrigation increased the soil's water potential and reduced soil moisture fluctuations in the productive root zone, which increased yield” Hanson et al. [20].

3.4 Specific Gravity (g/cm^3)

Data presented in Table 2 showed that the specific gravity of the crop at 60 and 75 days of planting was unaffected by the irrigation schedules and was not significant. The data clearly show that at irrigation level (I_1) 20 mm CPE, the specific gravity was highest (1.069 and 1.059). Hybrids are also non-significant.

The findings of the present study agreed with those of Amer et al. [21], and Arbogast et al. [22], who discovered that moisture deficit also has significant potential to enhance potato quality. With an increase in irrigation water volume, it was discovered that the specific gravity of potato tubers decreased Yuan et al. [23].

3.5 Nutrient (N, P, K) uptake by the 60 and 75 days of crop

3.5.1 Nutrient (N, P & K) uptake by the crop

Data revealed from Table 3 showed that irrigation levels significantly affected the N, P & K uptake by the crop, which increased significantly with the increase in irrigation level. The N, P & K uptake by crop was recorded maximum under Irrigation (I_1) 20 CPE of both 60 (107.7, 183.6, and 29.68 $kg\ ha^{-1}\ kg^{-1}$) and 75 (122.6, 201.6 and 33.16 $kg\ ha^{-1}\ kg^{-1}$) days of crop respectively. Hybrids also influenced the N, P & K uptake by the crop significantly which was different in different hybrids. Among hybrids, the maximum N, P & K uptake by the crop P-38 was reported at 60 (108.6, 212.1 and 30.01 $kg\ ha^{-1}\ kg^{-1}$) and 75 (123.9, 230.1 and 34.83 $kg\ ha^{-1}\ kg^{-1}$) days after planting. Similarly Badr et al. [24] in findings it has been also observed that both nitrogen rate and irrigation frequency at the shorter durations (daily, alternate, and weekly) intended to stimulate the pattern of potato N uptake more than the longest duration. The total nitrogen uptake was significantly higher with (I_1) irrigation 20 mm CPE than other levels.

Table 2. Effect of irrigation levels and potato hybrids on plant emergence, number of leaves, specific gravity and total tuber yield of 60 and 75 days crop

Irrigation levels	Plant Emergence	No. of Leaves	Specific Gravity of 60 Days crop	Specific Gravity of 75 Days crop	Tuber yield 60 days	Tuber yield 75 days
I ₁	96.4	82.8	1.069	1.059	329.6	457.8
I ₂	97.2	70.8	1.068	1.056	286.8	390.6
I ₃	93.8	59.9	1.067	1.055	192	243.8
I ₄	95.4	67.7	1.067	1.055	239.8	328.8
C.D. (5%)	N.S.	3.2	N.S	N.S	17.7	14.2
Hybrids						
V ₁	94.6	66.7	1.067	1.055	243.1	319.2
V ₂	96.8	74.3	1.073	1.065	290.1	393.8
V ₃	95.8	69.9	1.066	1.054	259.1	349.8
V ₄	95.1	68.8	1.068	1.056	250	340.9
V ₅	96.1	71.9	1.064	1.052	268	372.4
C.D. (5%)	N.S.	4.1	N.S	N.S	14.1	11.7

I₁:20 mm CPE, I₂:25 mm CPE, I₃:30 mm CPE and I₄:30 mm CPE + mulch

V₁: AICRP-P-21, V₂: AICRP-P-32, V₃: AICRP-P-37, V₄: AICRP-P-38 and V₅: Kufri Bahar

Table 3. Effect of irrigation levels and potato hybrids on nutrients uptake by the crop at 60 and 75 days crop and soil moisture at different stages

Irrigation levels	Nitrogen uptake 60 days	Nitrogen uptake 75 days	Phosphorus uptake 60 days	Phosphorus uptake 75 days	Potassium uptake 60 days	Potassium uptake 75 days	Soil moisture at stolen formation	Soil moisture at tuber initiation	Soil moisture at bulking stage
I ₁	107.7	122.6	183.6	201.6	29.68	33.16	18.5	18.2	18.6
I ₂	105.1	121	181.4	199.4	29	32.81	15.3	15	15.5
I ₃	102.7	119.8	172	190	28.93	32.44	11.9	11.6	12.1
I ₄	103.3	120.2	175.6	193.6	28.97	32.48	14.6	14.3	14.7
C.D. (5%)	0.7	0.1	0.7	0.6	0.03	0.33	0.67	0.6	0.7
Hybrids									
V ₁	102.6	115.4	152.3	170.3	28.77	31.02	14.7	14.3	14.8
V ₂	108.6	123.9	212.1	230.1	30.01	34.83	15.8	15.4	15.9
V ₃	103.9	122.3	176.3	194.3	29	32.72	13.9	13.6	14.1
V ₄	103.1	120.6	172	190	28.85	32.33	15.5	15.2	15.6
V ₅	105.4	122.4	177.9	195.9	29.11	32.72	15.6	15.3	15.7
C.D. (5%)	1.9	1.1	1.1	1.1	0.07	0.08	0.47	0.4	0.5

I₁:20 mm CPE, I₂:25 mm CPE, I₃:30 mm CPE and I₄:30 mm CPE + mulch

V₁: AICRP-P-21, V₂: AICRP-P-32, V₃: AICRP-P-37, V₄: AICRP-P-38 and V₅: Kufri Bahar

3.6 Periodical Soil Moisture Observations (at Stolen Formation, Tuber Initiation, and Bulking Stage) from 0-15 cm from Different Treatments

Data presented in Table 3 showed that the periodical soil moisture was significantly affected at different irrigation schedules with the irrigation level. The soil moisture was recorded maximum under Irrigation (I₁) 20 CPE in each stage *i.e.* stolen formation, tuber initiation, and bulking stage (18.5, 18.2, and 18.6) respectively. Hybrids also influenced the soil moisture significantly which differed in different hybrids., the maximum soil moisture among hybrids was registered at P-38 in each stage *i.e.* stolen formation, tuber initiation, and bulking stage (15.8, 15.4, and 15.9) respectively. Soil moisture has a major effect on crops. The results of the present study are in agreement with the finding Mahmood et al. [25] also reported that soil moisture content is generally higher as compared to western locations following an east-to-west decreasing precipitation gradient.

4. CONCLUSION

Drought has the potential to result in substantial productivity losses in tuber yield compared to mild or moderate stress. Additionally, it may affect how efficiently nutrients are absorbed, which is essential for a high tuber yield. This study used various irrigation levels to find high-yielding potato hybrids under water stress. This study shows that it is possible to achieve high tuber growth and nutritional composition. A combination of irrigation with 30mm CPE and 5 t/ha grass mulch results in increased tuber output. As opposed to non-mulched plots, mulched plots produce higher yields and require less water for irrigation, which is advantageous for tuber growth in water-stressed or low-water availability situations. It would be intriguing to examine in future research the effects of irrigation regimes with less severe water stress conditions to better understand irrigation levels, potato hybrids, and their growth.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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