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Effects of Deficit Irrigation on Potato Physical and Chemical Characteristics Under Different Planting Patterns

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Abstract

Conversion of potato from conventional sowing methods to bed planting systems may increase water use efficiency in commercial potato production system by reducing the amount of irrigation water. Potato is sensitive to water stress therefore, it reveals harsh effect on physical and chemical properties of potato. To investigate this issue a field experiment on autumn potato was conducted at Water Management Research Centre (WMRC), University of Agriculture Faisalabad (UAF) during 2014-2015. This study aims to investigate the effects of different irrigation methods and irrigation regimens on potato physical and chemical characteristics under altered planting configurations. Two planting patterns with irrigation treatments were ridge-furrow planting system with furrow irrigation (F) and bed-furrow planting system under drip irrigation (D) with three irrigation regimens included D_1= Full irrigation, D_2= 90% of full irrigation and D_3= 85% of full irrigation and was replicated thrice. Results showed that deficit irrigation poses severe effects on physical properties while didn’t have any significant effect on chemical properties of potato. Physical characteristics included physical dimensions (tuber length, thickness and diameter), shape index, weight analysis, actual and calculated volume, particle and bulk densities and repose angle. It was noted that treatment F showed higher average tuber length, thickness, weight, actual and calculated volume, particle density, bulk density and repose angle that were registered as 7.65 cm, 4.31 cm, 97.34 g, 86.25 cm^3, 80.44 cm^3, 1.13 g/cm^3, 563.36 kg/m^3 and 33^{o}50′ respectively while D_1 showed 1.75 shape index and D_3 showed higher tuber diameter 6.37 cm. While chemical properties included tuber moisture (%), TSS and starch content (%) that were registered as 79.3, 5.37 and 18.6 respectively in F. It was concluded that deficit irrigation severely affect the physical properties of potato therefore stress exercise isn’t recommended on potato at all.

INTRODUCTION

Water is vital for the survival of crops and the precise timing and application of moisture can boost both the quality and quantity of these crops. Water scarcity is one of the most pressing issues facing humanity today. Exploitation of ground water is intolerable due to energy crises. Freshwater is truly the essence of agriculture that can promise sustainable and consistent production of food. Agriculture accounts for 70% globally of all water withdrawn from streams and aquifers. Water scarcity is an important concern humanity facing nowadays. Over 1.4 billion individuals reside in water scared river basins and this figure is expected to touch 3.5 billion by 2025. This number is expected to reach 3.5 billion. Thus it becomes indispensable to properly manage water at all levels in order to fulfill their food and fiber requirements.

Resources of water are under stress in several parts of the world yet to meet the needs of energy and food for increasing population the demand for water is considerably increasing. There are issues that in some critical regions of the world the available water resources will decrease due to climatic changes and for agriculture drives the available area will continue to reduce as a result of land urbanization and degradation.

Water availability for crops is declining at very high rates as compared to the growing population and lack of sustainable and integrated management of natural resources in agriculture sector. That's why; we are having a lot of problems in this field. The total water resources reduced from 2,961 m^3 per individual in 2000 to 1,420 m^3 per individual in 2005. A latest study indicates an available supply of water of slightly more than 1,000 m^3/individual, which ranks Pakistan in the class of a highly stress country. Pakistan would slip below the water deficiency level 1,000 m^3 per individual, per annum in five years unless the water resources are managed properly. Globally, according to the impact of climate change the irrigation water availability may decline in the future (World Water Assessment Program, 2009) which may influence its cost and availability in future.

Water resources management at macro level is time taking and quite expensive, even though critical. In contrast, the management of water at farm level is comparatively feasible, inexpensive, easily practicable and can be implemented in the short duration of time. Farmers of Pakistan, normally apply irrigation water to unleveled fields, resulting poor water uniformity and low irrigation efficiency.

Potato (*Solanum tuberosum* L.) production takes a very important place in the agriculture of world, with a potential of production of about 327 million tons harvested and area of plantation is about 18.6 million ha (FAO, 2004). Early studies have shown that water is the most important limiting factor for potato production and it is possible to increase production levels by well-scheduled irrigation programs throughout the growing season (Boujelben *et al.*, 2001; Deblonde and Ledent, 2001; Faberio *et al.*, 2001; Chowdhury *et al.*, 2001; Panigrahi *et al.*, 2001; Ferreira and Carr, 2002; Kashyap and Panda, 2003; Shock *et al.*, 2003; Yuan *et al.*, 2003; Onder *et al.*, 2005). The average yield of Pakistan is less than yield of potato crop in different countries of the world (Kelman, 1984). The aim of this research was to determine the effects of furrow and drip irrigation methods under different planting configurations on potato physical and chemical characteristics.

MATERIALS AND METHODS

Experimental Site and Land Preparation

Field experiment on potato was carried out at Water Management Research Center- University of Agriculture Faisalabad Pakistan during the growing season (October- February) 2014-15. For the preparation and pulverizations of soil one time rotavator was applied then it was ploughed with cultivator then leveled. Then for the final preparation of experimental plots furrow makers and bed planter were used for making ridge-furrows and bed-furrows configurations respectively. For this research work total area was about 995.50 m^2. Total area was divided into two components of bed and furrows each area dimensions was 20ft×238ft and 5 ft. apart. Then this area was further divided into two segments each were 20 ft.×119 ft. Each experimental plot was measured 221.22 m^2 (13.72×36.28 m) and contained on an average 117 plants per row. Plots were separated by 5 feet distance from each other.

Installation of Drip Irrigation System

Drip irrigation system was designed and installed in the experimental field. This system was consisted of 110 mm PVC mainline connected to 50.8 mm PVC submain which further connected to 16 mm lateral line having built in emitters with average discharge 4 L/hr. In all the total 8 lateral line placed in the center of the bed between two plant rows. Each 119 ft. long lateral line having built-in emitters at 1 ft. apart. Flow meter and pressure gauge were installed in the main line to measure the applied volume of irrigation water and pressure respectively.

Preparation of Furrow Irrigation System

Leveled furrows were created by using laser leveler to ensure uniform water distribution. Furrows were closed at the end to prevent runoff and a volume of applied water was measured using cutthroat flume in furrow irrigation system. For this furrows and ridges were prepared by furrow maker. The plant to plant distance was maintained same as in bed-furrow configuration but row to row distance was 2.5 ft. in furrow irrigation system. The length of each furrow and ridge was 36.28 m, while each ridge was comprised of averagely 117 plants. Following formula was used to identify soil moisture contents (Singh *et al.*, 2005).

$$\theta = \frac{w_w - w_d}{w_d} \times 100$$

Sowing of Crop and Treatments

Selected healthy and disease-free potato tubers were sown manually at the depth of 10-12 cm on October 21, 2014 (Erdem, 2006). The experiment was organized in a separate plot scheme, four plots were made with two irrigation treatments under two planting patterns which were ridge-furrow planting system with furrow irrigation (F) and bed-furrow planting system under drip irrigation (D) with three irrigation schedules included D_1= Full irrigation, D_2= 90% of full irrigation and D_3= 85% of full irrigation and it was replicated thrice.

Physical and Chemical Characteristics of Potatoes

Physical characteristics of tubers at fresh were investigated. Physical characteristics included physical dimensions like length, diameter and thickness, shape index weight analysis, actual and calculated volumes. While, chemical properties included tuber moisture (%), TSS and starch contents (%). Vernier calipers was used for measuring the three axis of tuber (the major axis as tuber length (L-cm), the intermediate diameter as tuber width (D-cm) and the thickness of tuber (T-cm). Shape index of the measured samples was calculated using the following relation (Ismail *et al.*, 1988)

$$I = \frac{L}{\sqrt{DT}}$$

Where;

I = Shape index L = Length of tuber (cm)

T = Thickness of potato tuber (cm) D = Width of tuber (cm)

The suggested limits were used to compare the obtained data and classified into two main classes to specify the potato tubers according the calculated shape index.

Spherical shape ≤ 1.5

Oval shape ≥ 1.5

The actual volume of potato tubers was measured by immersing each tuber instantaneously in 500 or 1000 ml measuring cylinder filled with tap water to a fixed limit, the displaced water was measured and actual volume was calculated according the following relation:

$$V_{act} = \frac{W}{S_\rho}$$

Where;

V_{act} = Actual volume of tuber (mm^3)

W = Weight of displaced water (g)

S_ρ = Specific density of water (g/mm^3)

Calculated volume V_{cal} of individual tuber was determined by using the following relation according to (Mohsenin *et al.*, 1986).

$$V_{cal} = \frac{\pi}{6} \times (D.T.L)$$

Where;

V_{cal} = Calculated volume of individual tuber, cm^3

D, T and L are the diameter, Thickness and length of the tuber in cm respectively.

Particle density of potatoes was calculated as;

$$P_d = \frac{W}{V_{act}}$$

Where;

P_d = Particle density of individual tuber (g/cm^3)

W = Weight of potato tuber (g)

V_{act} = Actual volume of the individual potato tuber (cm^3)

Chemical characteristics included moisture content (%), TSS and starch content (%). Moisture content of fresh tuber was investigated. Total soluble solids and starch content of fresh tubers from each treatment were also measured.

RESULTS AND DISCUSSION

After harvesting of potato crop fresh tubers from each treatment were brought to the laboratory of Water Management Research Centre for analysis of physical and chemical characteristics. Main dimensions of tuber like length, width and thickness were measured using Vernier Calipers. These physical dimensions were used to determine the shape index of the individual fresh potato tuber to categorize the tubers into spherical and oval shapes. Results showed that most of the tubers were oval in shape. Average

Weight of each tuber/plant was measured on an electric balance that was registered as 97.34 g in F treatment. Other physical parameters actual and calculated volume, particle density, bulk density and repose angle were also measured and presented in Table 1. Climatic data was also measured to determine the CWR for this purpose temperature, rain fall, pan evaporation, sun shine hours, relative humidity, ET_o and wind speed was measured on daily basis and presented in figure 1. Average ET_o was found to be 1.66 mm throughout the growing season. Effective rain fall was calculated as (P-5)*0.75 which was 14.78 mm throughout the season. Actual CWR (Irrigation Need) in mm was registered as 156.75 and applied to treatment D_1.

Table 1: Data showing the average physical characteristics of tubers from each treatment.

Treatments	**Furrow irrigation (f)**	**Drip irrigation (D_1)**	**Drip irrigation (D_2)**	**Drip irrigation (D_3)**
Tuber length (cm)	7.65	7.29	7.42	6.50
Tuber width (cm)	5.06	4.43	5.83	6.37
Tuber thickness (cm)	4.31	3.80	3.64	4.03
Shape index of tuber	1.54	1.75	1.61	1.53
No. of tubers/plant	6.48	5.77	5.68	5.14
Average wt. of tuber/plant (g)	97.34	60.91	58.94	58.81
Avg. rooting depth (cm)	16.04	5.64	6.63	5.43
Actual volume of tuber (cm^3)	86.25	82.74	85.72	86.41
Calculated volume tuber (cm^3)	80.44	64.17	82.45	87.23
Particle density (g/cm^3)	1.13	0.74	0.69	0.68
Bulk density (kg/m^3)	563.36	584.21	579.38	569.86
Repose angle (dms)	$33^o50'$	$32^o45'$	$33^o55'$	$33^o28'$

Chemical characteristics included moisture content (%), TSS and starch contents (%) from each treatment were measured. Moisture contents of fresh tuber were also investigated. Total soluble solids were determined by using Hand Refractometer. A drop of juice was placed on clean prism of Refractometer and the lid was closed. Reading was taken from the scale at room temperature the procedure was repeated three times on tubers from each treatment to obtained average value and starch content of fresh tubers. Similarly starch contents were also measured and data of chemical properties presented in Table 2. However, results revealed that deficit irrigation poses severe effects on physical properties while didn't have any significant effect on chemical properties of potato.

Table 2: Data showing the average chemical characteristics of tubers from each treatment.

Treatments	Moinsture content (%)	Total soluble solids (°Brix)	Starch content (%)
Furrow Irrigation (F)	79.31	5.37	18.62
Drip Irrigation (D_1)	79.52	5.53	18.48
Drip Irrigation (D_2)	79.27	4.77	18.42
Drip Irrigation (D_3)	78.83	4.07	18.73

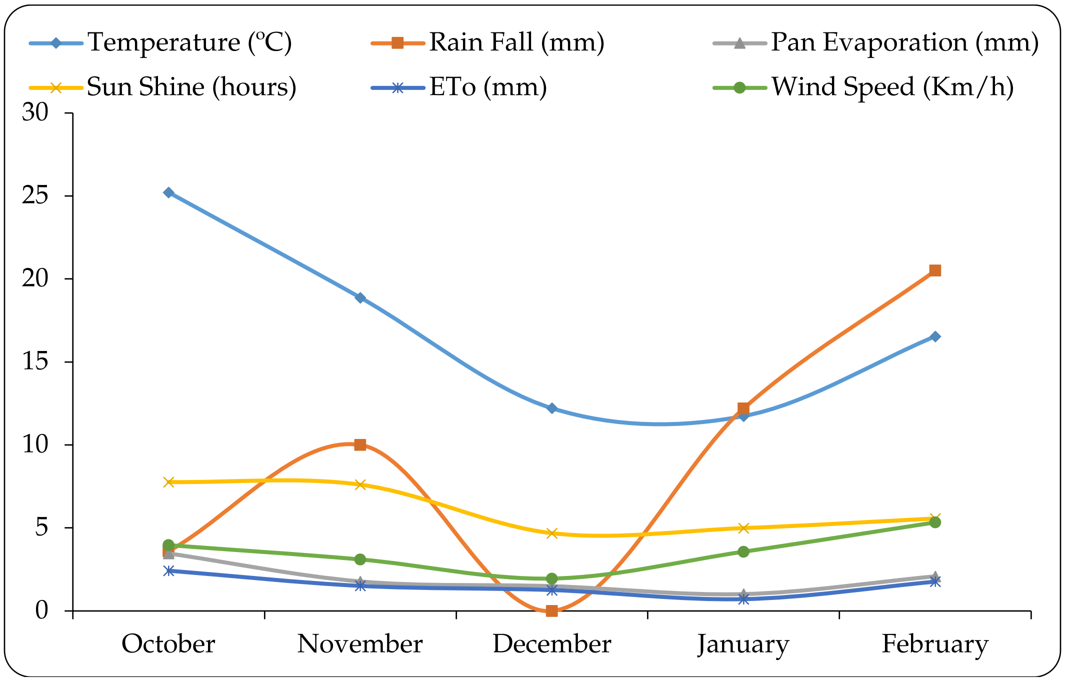

Figure 1: Data showing mean monthly temperature, rain fall, pan evaporation, sun shine hours, ET_o and wind speed.

It was concluded that deficit irrigation severely affects the physical properties of potato while did not have any significant effect on chemical properties that truly depends on quality and internal vigor of the seed. Therefore, stress exercise isn't recommended on potato at all. In context of water saving such management practices should be adopted as it didn't have significant effect on yield of potato crop.

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