Proceedings of Pakistan Society for Horticultural Science
2nd International Conference on Horticultural Sciences, February 18-20, 2016
Theme: Production Challenges and Food Security
Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Punjab 38040, Pakistan

Enhancing Water Productivity of Potato (*Solanum Tuberosum* L.) Through Drip Irrigation System

Muhammad Sohail Waqas* [1], Muhammad Jehanzeb Masud Cheema[1,2], Ahmad Waqas[3], Saddam Hussain[1]
[1]Department of Irrigation and Drainage, University of Agriculture, Faisalabad, Pakistan
[2]U.S.-Pakistan Center for Advanced Studies in Agriculture and Food Security (USPCAS-AFS), University of Agriculture, Faisalabad, Pakistan
[3]Water Management Research Centre, University of Agriculture, Faisalabad, Pakistan
Email: sohailwaqasrana@yahoo.com (M.S.W)

Abstract

Water deficiency is one of the most important factors restraining plant growth and dry matter which is the reduction of product quality and lack water soil or air, often during the plant life cycle. Therefore, there is dire need to adopt the modern efficient irrigation methods for crop production. To address this issue a field experiment on autumn potato was conducted at Water Management Research Centre (WMRC), University of Agriculture, Faisalabad (UAF). The study aims to determine the effects of different irrigation methods and irrigation regimens on potato yield and yield components. Two planting schemes with irrigation treatments were ridge-furrow sowing with furrow irrigation (F) and bed-furrow sowing under drip irrigation (D) with three irrigation schedules (i) irrigation to conserve the available water for crop (D_1), (ii) irrigation when 10% of the available water was consumed (D_2) and (iii) irrigation when 15% of the available water was consumed (D_3) and it was replicated thrice. Irrigation regimens influenced tuber yield, and tuber yield was registered as follows $F > D_1 > D_2 > D_3$. Water saving was recorded as 65%, 58% and 50% in D_3, D_2, D_1 respectively as compared to furrow irrigation. Tuber yield was recorded as 14.42 tons/acre, 11.80 tons/acre, 11.13 tons/acre and 10.45 tons/acre in F, D_1, D_2 and D_3 respectively. Percentage plant emergence was 97.83% in F and D_3. Average number of tubers/plant was found to be higher in F that is 6.48 and lessen in D_3 5.14. Maximum number of tillers was found in F. Manageable Allowed Deficit irrigation yield more non-marketable tubers while treatment F yield maximum number of marketable tubers. It was concluded that potato was severely affected by water stress and planting configuration did not had any significant effect on different traits.

INTRODUCTION

Agriculture is fundamental to economic development and food security in emerging countries. It provides source of employment for 3/4 of the world's poor. But food production needs significant amount of water. Resources of water are under stress in several parts of the world in order to meet the needs of energy and food for the increasing population, the demand for water will considerably increase. 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.

According to water security risk index 2010 given by Maplecroft for global risk analysis, Pakistan ranked at 7th position in the list of countries having extreme risk of water shortage (WSRI, 2010). However, water shortage perceived over the last several decades has crippled agricultural productivity and compelled the scientists to relay research efforts towards an efficient use of available water supplies. A dramatic jump in crop productivity can only be brought by shifting from conservative to conservation agriculture and improving water use efficiency of the crops. Studies in Pakistan shows that amount of water applied per irrigation is 13–18 cm, which is considerably higher than the two irrigation occasions of crop water requirement, i.e. almost 8 cm (Kahlown *et al.*, 2001) and at the field efficiencies of irrigation vary from 23 to 70% (Clyma and Ashraf, 1975; Kijne and Kuper, 1995; Kalwij, 1997; Kahlown *et al.*, 1998).

Potato (*Solanum tuberosum* L.) belongs to the family of *Solanaceae.* Potato is one of the most important cash crops amongst vegetables, being grown almost all over the world (Ewing, 1997). Potato ranks fourth among the agricultural products of the world in production volume, after wheat, corn and rice (Fabeiro *et al.*, 2001). It takes a significant place in the worlds' agriculture, with a potential of about 327 million tons and 18.6 million ha growing area (FAO, 2004).

Presently in Pakistan total annual domestic production is around 1.8 Million MT, of which 280000 MT is utilized as seed and 1.8 Million MT is available for consumption this accounts to 9300 g per person per annum. One hundred gram of fresh potato tuber contains about 80 ml of water, 2 g of proteins, 0.4 g of fiber, 17 g of carbohydrates, 10 mg of Calcium, 0.7 mg of Ferrous, 0.03 mg of riboflavin, 0.1 mg of thiamine and 1.5 of mg nicotinamide with small amount of ascorbic acid, insignificant amount vitamins C and fats (Tindall, 1968). That is why the importance of potato is increasing gradually due to increasing population pressure in our country (Malik, 1994).

Therefore, in view of the increased water shortage there is dire need to adopt water conservation, sowing techniques and modern high efficiency irrigation systems like drip and sprinkler irrigation. Drip irrigation technique offers vital benefits as compared to the method of surface irrigation, with higher yield, water use efficiency and better fertilizer application (Camp *et al.*, 2001). Drip irrigation method directly applies water to the root zone of plants and is not affected by high wind speed as compared to the sprinkler irrigation method (Sharma, 2001).

The aim of this research was to determine the effects of furrow and drip irrigation methods under different irrigation regimens on potato yield and yield components along with agronomic parameters for these conditions.

MATERIALS AND METHODS

Field experiment on potato was conducted at Water Management Research Center- University of Agriculture Faisalabad Pakistan during the winter growing season 2014-15. To determine the quality of irrigation water, water sample was analyzed for TSS, EC, SAR, pH and RSC and other constituents in the soil and water testing laboratory. Soil samples were also taken for determination of soil type, bulk density, field capacity, permanent wilting point, electrical conductivity, pH, organic matter, Phosphorous and Potassium percentage. For this research work total, experimental area was 995.50 m^2 (0.25 acre). Total area was divided into two fragments; bed-furrow configuration and ridge-furrow configuration each of 20ft. × 238ft. and 5 ft. apart in dimension. Then this area was further divided into two segments each with 20 ft.×119 ft. Each experimental plot was 221.22 m^2 (13.72 × 36.28 m) in dimension. There were four main plots that were laid down under split plot design and each treatment was replicated thrice. Data of pan evaporation, ET_o, temperature, relative humidity, rain fall, sun shine and wind speed on daily basis was taken from metrological observation of Experimental Research Centre of WMRC. The class A pan evaporation was used to measure evaporation and whose pan coefficient is 0.70. Time Domain Reflectometer (TDR) was used for estimating volumetric water content of soil. A Time Domain Reflectometer is a sophisticated and accurate piece of equipment and requires calibration. Calibration was done with gravimetric method. After preparation of beds and ridges drip irrigation system was installed. Coefficient of variance (CV), emission uniformity (EU) and field emission uniformity (EU_f) were calculated as follows to evaluate the performance of drip irrigation system.

$$Cv = \frac{\sigma}{q_{avg}} \times 100 \quad (1)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(q_{min}-q_{avg}\right)^2}{n}} \quad (2)$$

Keller and Karmeli (1974) developed two formulas to estimate the design emission uniformity for trickle (drip) irrigation systems; these formulas are expressed as follows,

$$EU = 100\left[1 - 1.27\frac{cv}{\sqrt{n}}\right]\frac{q_{min}}{q_{avg}} \quad (3)$$

Where, Cv is coefficient of variation, n is the number of emitters, q_{min} is minimum flow and q_{avg} is average flow.

Merriam and Keller (1978) expressed field emission uniformity as follows.

$$EU_f = \frac{q_{1/4}}{q_{avg}} \times 100 \quad (4)$$

Where, EU_f is the field emission uniformity expressed as a percentage and $q_{1/4}$ is average discharge of the emitters on quarter of the area receiving the least amount in the tested subunit in lph.

Following formula was used to determine soil moisture status of the soil by the gravimetric method (Singh *et al.*, 2005).

$$\theta = \frac{w_w - w_d}{w_d} \times 100 \quad (5)$$

Where, θ is moisture content on dry weight basis in percentage, W_w is wet weight of soil in g and W_d is oven dry weight of soil in g.

The percentage depletion of ASM in the effective root zone was estimated using following formula (Martin *et al.*, 1990).

$$MAD(\ \ ) = 100 \times \frac{1}{n}\sum_{1}^{n}\frac{FC_i-\theta_i}{FC_i-\wp} \quad (6)$$

Where, n is the number of sub-divisions of the effective rooting depth, θ_i is soil moisture in i^{th} layer (%), FC_i is soil moisture at field capacity for i^{th} layer (%) and WP is the soil moisture at permanent wilting point (%).

The amount of water was applied after the attainment of predefined MAD (%) was calculated as follow (Martin *et al.*, 1990).

$$V_d = \frac{MAD(\ \ )\times(FC-\wp)\times R_z\times A}{100} \quad (7)$$

Where, V_d is the volume of irrigation water in m^3, R_z is the effective rooting depth in m and A is surface area of the plot in m^2.

The water saving in drip over furrow irrigation system was calculated as under (Ibragimov *et al.*, 2007):

$$W_S = \frac{W_f-W_d}{W_f}\times 100 \quad (8)$$

Where, W_S is the water saving in percentage, W_f is total water used in furrow irrigation system in m^3/ha and W_d is total water used in drip irrigation system in m^3/ha.

The water productivity (W.P) of furrow and drip irrigation systems was calculated by using following formula (Wichelns, 2014).

$$W.P = \frac{Y}{W_c} \quad (9)$$

Where, W.P is the water productivity in Kg/m^3, Y is crop yield in Kg/hac and W_c is the total water consumed in m^3/hac.

RESULTS AND DISCUSSION

Soil analysis was carried out to determine the soil type, bulk density, field capacity, permanent wilting point, electrical conductivity, pH, organic matter, Phosphorous and Potassium percentage which found to be Sandy Loam, 1.5 g/cc, 19.1%, 8.4%, 8.3, 1.3 dS/m, 0.45%, 1.8 ppm and 100 ppm respectively. Similarly, water sample was also investigated for assurance of irrigation water quality parameters that includes pH, EC (dSm^{-1}), TSS (ppm), SAR and RSC (meL^{-1}) were found to be 6.80, 1.643, 1052, 5.64 and 0.60 respectively. The coefficients of variation (CV) and emission uniformity (EU) of randomly selected laterals were determined at 16 psi, 18 psi and 20 psi pressures to test the performance of the drip irrigation system. The results are presented in Table 1 which showed that the coefficient of variation of randomly selected laterals was 0.076, 0.081 and 0.101, respectively. Similarly, the emission uniformity of randomly selected laterals was found to be 92.434, 91.895 and 89.881% respectively. These results advocated that the system was working satisfactorily according to its design.

Table 1: Data showing minimum discharge, average discharge, standard deviation, coefficient of variation and emission uniformity.

Pressure (psi)	**Minimum discharge q_m (lit/hr)**	**Average discharge q_{avg} (lit/hr)**	**Standard deviation σ**	**Coefficient of variation (Cv)**	**Emission uniformity (EU)**	**Field emission uniformity (EU_f)**
16	2.82	3.17	8.05	0.076	92.43	94.33
18	2.75	3.05	8.38	0.081	91.90	92.99
20	3.09	3.62	12.32	0.101	89.88	91.68

Agronomic parameters were also determined. Percentage plant emergence was registered as 97.83, 97.48, 96.28 and 97.53 in F, D_1, D_2 and D_3, respectively. Other agronomic parameters; Average no. of tubers/plant, average no. of tillers/plant, average no. of marketable category I, average no. of marketable category II and non-marketable tubers/plant were also determined and results are showed in figure 1. Results revealed that tuber yield was significantly influenced with different irrigation schedules that were recorded as 14.42 ton/acre, 11.80 ton/acre, 11.13 ton/acre and 10.45 ton/acre in F, D_1, D_2 and D_3, respectively. As a part of core objective of this research amount of irrigation water was saved that was documented as 65%, 58% and 50% in D_3, D_2, D_1 treatments respectively as compared to furrow irrigation treatment (F). While, a drastic increase in water productivity was achieved on the behalf of water saving which are plotted in figure 2.

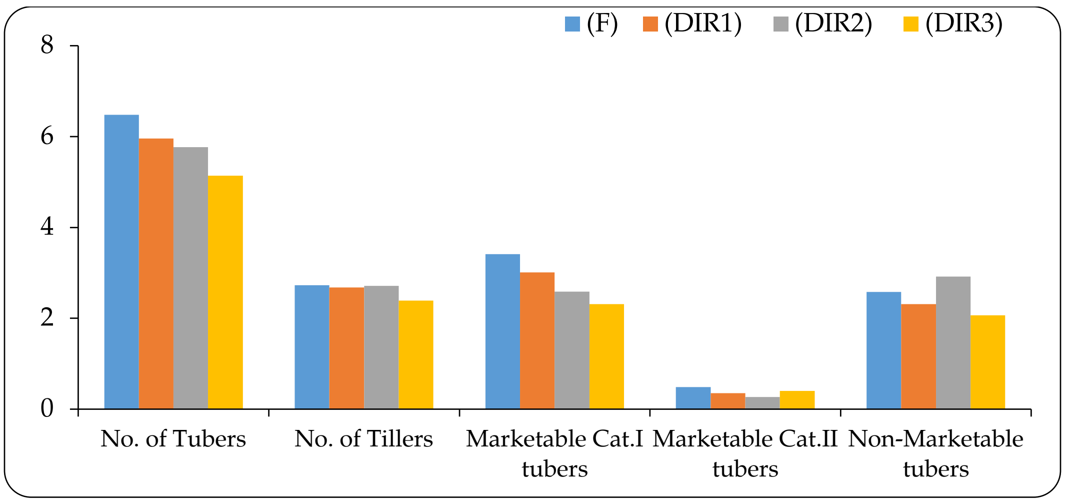

Figure 1: Data showing average no. of tubers/plant, no. of tillers/plant, no. of marketable category I tubers, no. of marketable category II tubers and non-marketable tubers/plant.

Results agreed with the facts presented in literature indicated that potato being the most sensitive crop to water stress if there will be a moisture stress, occurring before the onset of tuber initiation and thereafter, effectively reduced the number and weight of tubers (Mackerron and Jefferies, 1986). Moreover, there had been many reports on the effects of water deficiency and irrigation regimes on potato crop in many parts of the world (Ojala *et al.,* 1990; Silva *et al.,* 1990; Kincaid *et al.,* 1993; Fabeiro *et al.,* 2001; Yuan *et al.,* 2003; Onder *et al.,* 2005; Kaur *et al.,* 2005), which shows that water deficiency causes a reduction of yield by reducing growth of crop canopy and biomass that may be due to the reason that crop had low tolerance for water stress (Patel, 2007; Badr *et al.,* 2012). Similarly, when potatoes were planted on wide beds tuber growth (88.7%), average no. of stems plant^{-1} (3.5), average no. of tubers plant^{-1} (10.1) and yield (12.4 t/ha) were higher as compared to ridge sowing. Maximum no. of green and injured potatoes was detected 12.5 and 5.3% respectively when potatoes were planted according to the indigenous farmer's method (Qasim *et al.,* 2013).

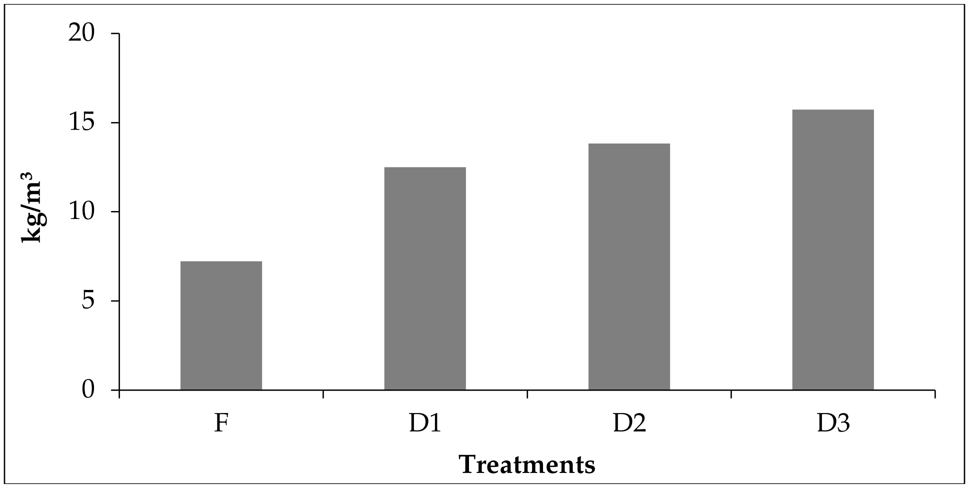

Figure 2: Data showing water productivity in kg/m³.

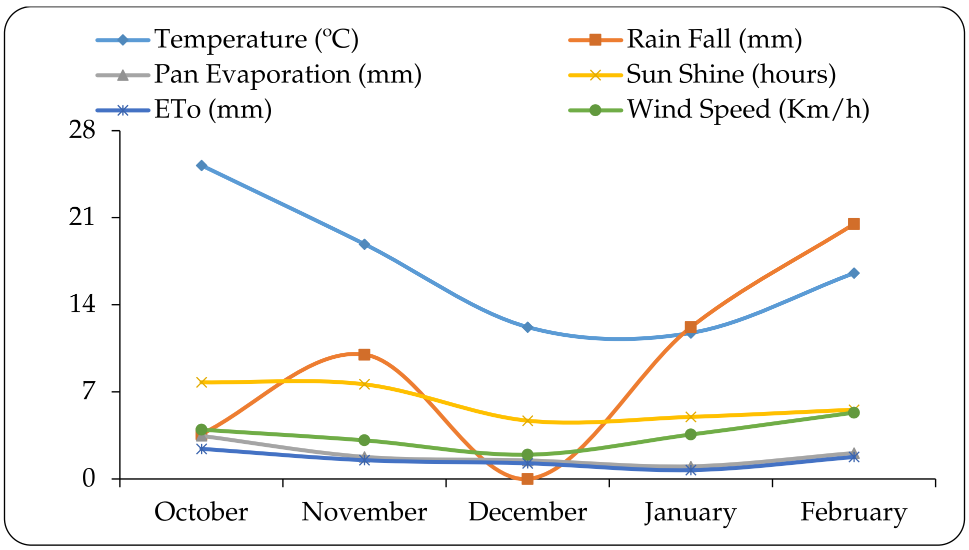

Figure 3: Data showing mean monthly temperature, rain fall, pan evaporation, sun shine hours, ET_o and wind speed.

REFERENCES

Badr, M.A., W.A. El-Tohamy and A.M. Zaghloul. 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.

Camp, C.R., E.J. Sadler, W.J. Busscher, R.E. Sojlka and D.L. Karrlin. 2001. Experiencing with sprinkler irrigation for agronomic crops in the South-Eastern USA.

Clyma, W.A. and M.M. Ashraf. 1975. Irrigation practices and application efficiencies in Pakistan. In Water Management Research Project. Water Management Technical Report No. 39, Colorado State University, Fort Collins, Colorado, USA.

Ewing, E.E. 1997. The physiology of vegetable crops (Ed: H.C. Wien). CAB intern.UK.295-344.

Faberio, C., F.M.S. Olalla, J.A. Juan. 2001. Yield size of deficit irrigated potatoes. Agriculture and Water Management.48:255-266.

FAO Stat. Agriculture. Rome. 2006. Available in: http://faostat.fao.org/FAOSTAT. Accessed at: June 2004. FAO.

Ibragimov, N., S.R. Evtt, Y. Esanbekov, B.S. Kamilov, L. Mirzaev and J.P.A. Lamers. 2007. Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. Agricultural Water Management. 90 (1/2):335-238.

Kahlown, M.A., A. Raoof and M. Hanif. 2001. Plant population effect on paddy yield. J. Drain. Water Manage. 5 (1):1–5.

Kahlown, M.A., M.S. Shafique and M. Iqbal. 1998. Improved irrigation methods for efficient use of irrigation water under different water-table depths. Mona Reclamation Experimental Project, WAPDA, Bhalwal. p:231.

Kalwij, I.M. 1997. Assessing the Field Irrigation Performance and Alternative Management Options for Basin Surface Irrigation Systems Through Hydrodynamic Modeling. Report No. 35. International Water Management Institute, Pakistan.

Kaur, M.N. and J.K. Chawla. 2005. Irrigation and potassium management in trickle fertigated potato *Solanum tuberosum* L. Indian Journal of Agricultural Science. 75(5):290-292.

Keller, J. and D. Karmeli. 1974. Trickle Irrigation Design Parameters, Transactions of the American Society of Agricultural Engineering.

Kijne, J.W. and M. Kuper. 1995. Salinity and sodicity in Pakistan's Punjab: a threat to sustainability of irrigated agriculture. J. Water Resource. Dev. 11 (1).

Kincaid, D.C., D.T. Westermann and T.J. Trout. 1993. Irrigation and soil temperature effects on Russet Burbank quality. American Potato Journal. 70(10): 711-721.

Mackerron, D.K.L. and R.A. Jefferies. 1986. The influence of early soil moisture stress on tuber numbers in potato. Potato Research. 29 (3):299-312.

Malik, M.N. 1994. Horticulture. National Book Foundation, Islamabad. p. 269-271.

Maplecroft. 2010. Water Security Risk Index. Retrieved from http:// maplecroft. Com / about /news/watersecurity. html.

Martin, D.L., E.C. Stegman and E. Freres. 1990. Irrigation scheduling principles. In: Hoffman, G.L., T.A. Howell, K.H. Solomon (Eds.), Management of Farm Irrigation Systems. ASAE Monographp. 155–372.

Merriam, J. and J. Keller. 1978. Farm Irrigation System Evaluation. A Guide for Management, Agriculture and Irrigation Engineering Department, Utah State University. p. 120-230.

Ojala, J.C., J.C. Stark and G.E. Kleinkopf. 1990. Influence of irrigation and nitrogen management on potato yield and quality. American Potato Journal. 67(1):29-43.

Onder, S. 2005. Different irrigation methods and water stress effects on potato yield and yield components. Agricultural Water Management. 73 (1):73-86.

Patel, N. and T.B.S. Rajput. 2007. Effect of drip tape placement depth and irrigation level on yield of potato. Agricultural Water Management. 88(1-3):209-223.

Qasim M., S.Khalid, A.Naz, M.Z. Khan and S.A. Khan. 2013. Effects of different planting systems on yield of potato crop in Kaghan Valley: A mountainous region of Pakistan. Agricultural Sciences. 4. :175-179.

Sharma, B.R. 2001. Availability, status and development and opportunities for augmentation of groundwater resources in India. Proceeding ICAR-IWMI Policy Dialogue on Ground Water Management, November 6-7 at CSSRI, Karnal. 1-18.

Silva, G.CR.W. and R.B. Kitchen. 1990. Irrigation management and supplementary calcium in relation to specific gravity and internal defects of potatoes. 75th Annual Meeting of the Potato Association of American. Quebec, Canada.

Singh, N., M.C. Sood and S.S. Lal 2005. Evaluation of potato based cropping sequences under drip, sprinkler and furrow methods of irrigation. Potato Journal. 32(¾): 175-176.

Tindall, D. 1968. Commercial vegetable growing. The English language book society. Oxford uni. Press. 210.

Wichelns, D. 2014. Do estimates of water productivity enhance understanding of farm-level water management? Water 6(4): 778-795.

Yuan, B.Z., S. Nishiyama and Y. Kang. 2003. Effects of different irrigation regimes on growth and yield of drip-irrigated potato. Agricultural Water Management. 63(3):153-167.