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Original Research

Evaluation of Different Moisture Depletion Levels for Water Productivity, Yield and Tuber Size of Potato under Drip Irrigation

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ABSTRACT

A field experiment comprised of four different levels of management allowable depletion (MAD) of soil moisture for next irrigation to potato crop under drip irrigation was conducted during 2017-18 and repeated during 2018-19 at Water Management Research Farm, Renala Khurd, Okara, Pakistan. Cropwat 8.0 program was used to determine the interval and depth of next irrigation at 15, 30, 45 and 60% MAD of soil moisture. The experiments during both the years were organized in RCBD fashion with four replications. Irrigation to potato crop at 30% MAD level depicted the highest water productivity (17.28 kg/m^3), followed by 60%, 15% and 45% MAD levels with water productivity values of 16.90, 16.63 and 14.60 kg/m^3, respectively. The highest tuber yield was obtained when potato crop was irrigated at 60% MAD level (28.411 tons ha^{-1}), followed by 30% MAD level (27.998 tons ha^{-1}), 15% MAD level (26.736 tons ha^{-1}) and 45% MAD level (24.081 tons ha^{-1}). The maximum %age of medium sized tubers was achieved by applying irrigation to potato crop at 60% MAD level (65.70), followed by 30% MAD level (65.50), 45% MAD level (64.00) and 15% MAD level (60.50). The incidence of scab was found 2.50%, 2.75%, 3.25% and 3.75% in potato tubers at 15, 30, 45 and 60% MAD level, respectively indicating that the incidence of disease increased slightly with increase in MAD level.

Keywords: *Irrigation scheduling, management allowable depletion (MAD), scab incidence, Solanum tuberosum, tuber yield.*

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important food crop, and it stands at fourth position in production after corn, rice and wheat at world level. It provides strength (carbohydrates) in the food chain and cheap source of calories to meet the need of increasing population. In Pakistan, the area and production of potato during 2017-18 were 187.2 thousand hectare and 3854 thousand tons, respectively (Anonymous, 2018).

Irrigation water is very valuable input for production of potato crop. Under the current scenario, population of the country is increasing, while availability of water per capita is decreasing day by day. According to water security risk index of 2010 for global risk analysis, Pakistan ranked at seventh position in the list of countries having extreme risk of water shortage (Maplecroft, 2010). Studies in Pakistan shows that amount of water applied per irrigation is 13-18 cm, which is considerably higher than the two irrigations of crop water requirements, 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). The situation is alarming if the water productivity and yield of food crops are not improved. 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; Ferreira and Carr, 2002; Kashyap and Panda, 2003; Shock et al., 2003; Yuan et al., 2003; Onder et al., 2005). In view of the increased water shortage, better management of water application is required for farmers seeking a viable mean to maximize water use and to increase yield. To achieve this goal, there is dire need to adopt water conservation, sowing techniques and modern high efficiency irrigation systems.

Present study was conducted with the objective to find most optimal interval between the two irrigations to the potato crop by using Cropwat 8.0 program and determination of most suitable irrigation depth to be applied for higher per hectare yield, water productivity (kg of potato produced by using 1 m^3 of irrigation water), %age of marketable size (medium + large) of tubers and the incidence of scab disease under different levels of soil moisture depletion.

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MATERIAL AND METHODS

A field experiment was conducted at Water Management Research Farm (WMRF), Renala Khurd District Okara, Punjab, Pakistan during 2017-18 cropping season and repeated during 2018-19. Research experiment comprised of four MAD levels i.e., 15, 30, 45 and 60% MAD of soil moisture, which were applied for irrigation to potato cultivar "Karoda" in a RCBD (randomized complete block design) with four replications under drip irrigation system. These MAD levels were used keeping in view the critical growth stages of potato crop where moisture depletion/availability is very detrimental. Moreover, these levels were observed pivotal in the field studies conducted at Potato Research Institute, Sahiwal in the previous years. The description of experimental treatments is given below.

15% MAD = Irrigation was done when soil water content was depleted to 15% of the available water.
30% MAD = Irrigation was done when soil water content was depleted to 30% of the available water.
45% MAD = Irrigation was done when soil water content was depleted to 45% of the available water.
60% MAD = Irrigation was done when soil water content was depleted to 60% of the available water.

Cropwat 8.0 program was used to calculate the irrigation depth for all the four MAD levels. A measured quantity of irrigation water was applied to each treatment to maintain the soil moisture content according to the MAD levels through drip irrigation system. The plot size was maintained as 4.30 m x 14 m for each treatment. Seed tubers were planted on October 26 during 2017 and on October 30 during 2018. The plant-to-plant distance was maintained as 15 cm, whereas paired row to row distance was maintained as 60 cm. The drip laterals were placed between the paired rows. All other agronomic and cultural practices adopted up to maturity of the crop were standard and uniform. The crop was harvested on March 08 during 2018 and March 07 during 2019.

Data regarding tuber yield and water productivity were collected per plot basis, while other parameters like small, medium, and large sized tubers were taken in percentage from the sample of 100 randomly selected potatoes from each plot. Water productivity is economic yield produced by a unit volume of irrigation, which was determined by using the following formula.

$$\text{Water productivity (kg m}^{-1}) = \frac{\text{Yield (kg)}}{\text{Volume of irrigation water applied (m3)}}$$

The incidence of scab disease was estimated by using the following formula.

$$\text{Scab (\%)} = \frac{\text{Number of infected tubers}}{\text{Total number of tubers}} \times 100$$

The data collected during two years' experiments were pooled, averaged and then analyzed using Statistix 8.1 program for analysis of variance (ANOVA) and least significant difference (LSD) for treatment means at 5% level of significance. The statistical results were inferred as described by Steel et al. (1997).

RESULTS

Potato tuber yield influenced by various MAD levels

Data on tuber yield are presented in Table 1. The highest potato tuber yield (28.411 tons ha^{-1}) was obtained with irrigation at 60% MAD level, which was statistically similar with the tuber yield obtained at 30% (27.998 tons ha^{-1}) and 15% (26.737 tons ha^{-1}) MAD levels. The lowest tuber yield was harvested with irrigation at and 45% MAD level (24.081 tons ha^{-1}), followed by at 15% MAD level (26.737 tons ha^{-1}). These two MAD levels were statistically at par.

Water productivity under different MAD levels

Results of water productivity under drip irrigation system with different MAD levels regarding potato crop are shown in Table 2. The statistical results indicated that the water productivity of potato cultivar "Karoda" was significantly varied among the MAD levels used. The water productivity under different MAD levels applied ranged from 14.60 to 17.28 kg m^{-3}. The maximum water productivity (17.28 kg m^{-3}) was noted with irrigation at 30% MAD level, followed by 60% and 15% MAD levels with water productivity values of 16.90 and 16.63 kg m^{-3}, respectively. The minimum water productivity (14.60 kg m^{-3}) was noted with irrigation at 45% MAD level which was statistically similar with 15% MAD level (16.63 kg m^{-3}).

Effect of different MAD levels on size of potato tubers

The results presented in Table 3 elucidated that size of potato tubers was not affected significantly by different MAD levels. However, medium sized tubers were obtained more under 60% MAD level followed by 30% and 45% MAD levels, while smaller sized tubers were produced lesser in case of 45% MAD level followed by 60% MAD level.

Effect of different MAD levels on incidence of scab on potato

Table 4 showed that occurrence of scab disease on potato tubers

Table 1: Means for potato tuber yield under drip irrigation with different MAD levels.

Treatment	Tuber yield (tons ha^{-1})
15% MAD	26.736 ab
30% MAD	27.998 a
45% MAD	24.081 b
60% MAD	28.411 a
LSD (0.05)	2720.70

Means followed by different letters differ significantly at $P < 0.05$ (LSD test).

Table 2: Means for water productivity under drip irrigation with different MAD levels.

Treatment	Water productivity (kg m^{-3})
15% MAD	16.63 ab
30% MAD	17.28 a
45% MAD	14.60 b
60% MAD	16.90 a
LSD (0.05)	1.655

Means followed by different letters differ significantly at $P < 0.05$ (LSD test).

Table 3: Effect of applying irrigation with drip system at different MAD levels on the size of potato tubers.

Percentage of different sizes of tubers			
Treatment	Medium (35-55 mm)	Large (>55 mm)	Small (<35 mm)
15% MAD	60.50	18.75	20.75
30% MAD	65.50	15.25	21.75
45% MAD	64.00	17.75	18.25
60% MAD	65.75	15.75	18.50

Table 4: Means of incidence of scab disease on potato tubers under drip irrigation with different MAD levels.

Treatment	Scab incidence (%)
15% MAD	2.50
30% MAD	2.75
45% MAD	3.25
60% MAD	3.75

ranged from 2.50 to 3.75%, however it was not affected significantly by the MAD levels. It was observed 2.50% at 15% MAD level, and 3.75% in 60% MAD level, whereas scab incidence was recorded 2.75% and 3.25% in 30% and 45% MAD level, respectively recorded with SCHAAL scale.

DISCUSSION

The potato crop has usually been considered shallow rooted and sensitive to water. It is not usual to apply water frequently and in excess. Results revealed that tuber yield was significantly influenced with different MAD levels. The highest yield was obtained with 60% MAD level. Previous researchers also reported that potato production could be increased by well-scheduled irrigation programs throughout the growing season (Chowdhury et al., 2001; Panigrahi et al., 2001).

The results relating to water productivity revealed that the maximum water productivity was obtained with 30% MAD level followed by 60% MAD level, 15% MAD level and 45% MAD level. It clearly shows the superiority of most optimal interval between the two irrigations to the potato crop regarding judicious use of water and quality production of potato tubers with respect to their cosmetic value (less scab incidence). Our results corroborate the findings of previous researchers. Several authors reported that water productivity values for tuber yield that are higher under deficit than under adequate irrigation (Darwish et al., 2006; Fabeiro et al., 2001; Islam et al., 1990; Kashyap and Panda, 2003; Onder et al., 2005; Badr et al., 2012). Kang et al. (2004) and Onder et al. (2005) also registered similar water-use efficiency (WUE) values for potato. Hence, it is not advisable to apply excessive water. Higher application of water may lead to non-evapotranspiration losses like deep percolation and excessive soil moisture. Efficient and economical management of precious water is prime concern for farmers.

In market, quality standard must be met for higher returns, particularly with regard to tuber size and shape. The size of potato tubers could be affected by water application period. The results of present study indicated that higher percentage of medium and large size potatoes were obtained in 60% MAD level, whereas higher percentage of small sized potato were resulted in case of 30% MAD level followed by 15% MAD level, indicating that water deficit had adverse effect on quality and yield of potato. Other researchers have also reported the same results (Ferreira and Carr, 2002; Kashyap and Panda, 2003; Shock et al., 2003; Yuan et al., 2003; Kang et al., 2004).

The marketable tuber yield, appearance and quality of potato crop is also affected by a common potato tuber disease called scab. It can be controlled by managing soil moisture through proper irrigation (Delahaut and Stevenson, 2009). Current study revealed that incidence of scab increased with increase in irrigation interval. The results illustrated that incidence of scab ranged from 2.50 % to 3.75 %. It was the lowest at 15% MAD level, and the highest at 60% MAD level.

CONCLUSION

The improvement in drip irrigation scheduling results in better potato yield, accompanied by large savings in the amounts of irrigation water. This practice is highly effective for water management program for potato crop production and to increase farm income under local conditions. To improve the yield, marketable tuber size, water productivity and cosmetic value of potato, 60% MAD level could be adopted for irrigation of this crop under drip irrigation system.

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