JOURNAL OF AGRICULTURE AND BASIC SCIENCES
ISSN Online: 2518-4210
http://www.jabsjournal.com/

Full Length Research Article

Potato yield and water productivity response to different fertigation regimes under drip irrigation system

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Abstract

It is well known that flooding and high application of fertilizers increases the cost of inputs and reduce the crop yield. The maximum yield can be obtained with fertigation through increasing water and fertilizer use efficiency. In order to study the optimum fertigation level for higher yield and water productivity under drip irrigation a field experiment was conducted on potato during the winter season of 2018-19 at Water Management Research Farm, RenalaKhurd, Okara, Pakistan. The experiment comprised of four fertigation levels i.e., F_1 (100% of recommended dose of NPK fertilizer), F_2 (75% of recommended dose of NPK fertilizer), F_3 (50% of recommended dose of NPK fertilizer) and F_4 (25% of recommended dose of NPK fertilizer) was laid out in RCBD with 4 replications. It was noted that under F_2, the potato yield (26852 kg/ha) was highestof all treatments whereas F_1, F_3 and F_4produced 22083, 20019 and 19547 Kg/ha yield respectively. Similarly, the irrigation water productivity was highest (15.20 Kg/m3) under F_2 compared with F_1(12.50), F_3(11.32) and F_4(11.07). Marketable potato tuber sizes S_2(35-55 mm) and S3(Large < 55 mm) under F_2 was comparatively higher than F_1, F_3, and F_4. The percentage of Scab disease in F_2 was 3.5%. In this present study, the effect of F_2 (75% of recommended dose of NPK fertilizer) was concluded to be the best in terms of tuber yield and water productivity, under drip irrigation system.

Keywords: Fertigation, Levels, Optimum, Tuber size, Marketable Potato, Water Productivity

Introduction

Potato is an important crop after cereals with a potential of earning a significant amount of foreign exchange. China is largest producer of potatoes with production of 99.14 million metric tons (FAOSTAT, 2019). In Pakistan, out of total 3831.7 million metric tons of production, Punjab, Sindh KPK and Baluchistan are producing 3660.3, 5.6, 143.4 and 22.4 million metric tons respectively (Govt. of Pakistan, 2017).

Potato crop have a shallow root system and have relatively high demand for many nutrients. Therefore, a sufficient amount of fertilizers is required for maintaining a healthy potato crop, optimum tuber size and yield. Supply of Nitrogen, Phosphorus and Potassium plays an important role in growth and yield of potato. Nitrogen is an essential component of protein and chlorophyll, Phosphorus contributes to early plant development, tuber formation and enhances tuber maturation, whereas potassium influences tuber quality and yield along with enhancement of plant resistance against drought and frost.

An excessive amount of N fertilizer can cause groundwater contamination with nitrate, especially under heavy irrigation (Stark *et al*., 1993). This traditional practice has led to lower, nutrients and water-use efficiencies and to a low marketable yield of Potato (Al-Harrire, 2000).Therefore, the adoption of drip fertigation and other new irrigation techniques based on the application of precise water and fertilizer for Potato production may reduce groundwater contamination while increasing crop yield and reducing fertilizer, water, and energy inputs (Stark *et al*., 1993) The wide range of water use efficiency (WUE) and marketable tuber yield values are required to be addressed through better irrigation and fertilizer management.

To gain the optimum benefits under such situation, proper irrigation and fertilization scheduling is needed. Employment of fertigation systems allow proper water, fertilizer management and permit better control of soil moisture (Darwish *et al*., 2003; Janat and Somi, 2001). In conjunction with precise exact irrigation schedule, by use of direct soil moisture monitoring methods and a specified allowable depletion of soil moisture, fertigation could be used to rationally manage the irrigation water and fertilizers. Careful irrigation schedule and N-fertilizer application could improve N uptake, N- and water-use efficiency, crop yields, and reduce nitrate leaching into the groundwater (Janat and Somi, 2001; Eldredge *et al*., 1996).

Although intensive investigations on fertilizer and water requirements are available, they have mostly dealt with those two factors separately. Few studies have investigated the combined effects of fertilizer and water on Potato crops grown under fertigation (Mohammad *et al*., 1999; Darwish *et al*., 2003; Papadopoulos, 1988). The objective of this study was to analyze potato yield, water productivity, tuber sizes, and disease attack affected by different

fertilizer application rates using drip irrigation system.

Materials and Methods

The present study was conducted at Water Management Research Farm (WMRF), Renala Khurd Okara, Pakistan (altitude 170 m, 73°36 E and 30°53″ N), during the winter season of 2018-19. A commercial potato cultivar "Karuda" was grown with plant-to-plant distance maintained as 15 cm, whereas paired row to row distance was maintained as 60 cm on loamy soil. The experiment was setup in a randomized complete block design (RCBD) with four replications for each treatment. The Four treatments i.e. F_1(100% of recommended dose of NPK fertilizer), F_2 (75% of recommended dose of NPK fertilizer), F_3 (50% of recommended dose of NPK fertilizer) and F_4 (25% of recommended dose of NPK fertilizer) were applied through drip irrigation system. Plot size was 4.30 m × 14 m and separated by a 60 cm wide ridge to prevent water and fertilizer flow between neighboring plots. All other standard agronomic and cultural practices were followed up to crop maturity. The crop was harvested after128 days of sowing. The Data regarding tuber yield and water productivity was collected per plot basis. The potato tubers categorized into three sizes S1 (small, <35 mm in diameter), S2 (medium, 35-55 mm in diameter and S3 (large > 55 mm in diameter) were taken in percentage from the sample of 100 randomly selected potatoes from each plot. Similarly, the incidence of the scab was noted in percentage from a randomly selected 100 potato tubers from each plot. All the collected data were analyzed by utilizing statistical software Statistix 8.1 (Statistix Analytical Software, Tallahassee, Florida), while the differences amongst treatments were separated according to least significant difference (LSD) test at a 5% probability level.

Results

Potato yield influenced by various fertilizer treatments:

Potato yield was ranged from 19547 to 26852 kg ha^{-1}, as depicted in table 1. Highest value of potato yield was observed at F_2, while lowest was noted at F_4. It was observed that at F_2 the potato yield was 26852 kg ha^{-1} which is 21.59, 34.13, 37.37% higher as compared to F_1, F_3 and F_4 respectively. It creates an opportunity that low rate of fertilizer application could also give desired potato yield through proper management of fertilizer via drip irrigation system (Table 1).

Effect of different fertilizers levels on sizes of potato tubers

The table 2 elucidated that potato tuber sizes S_2 and S_3 under F_2 was comparatively higher than F_1, F_3, and F_4, except S_1.The medium sized tuber ranged from 66% to 69.2%.The highest value of medium sized tubers was obtained under F_2 treatment, while the lowest was observed in F_4 treatment.

Improvement of irrigation water productivity under various fertilizer treatments

Irrigation water productivity was ranged from 11.07 to 15.20 kg m^{-3}, as showed in table 3. Results revealed that significant differences were observed between $F_2$and F_4 fertilizer treatments for irrigation water productivity at 5% level of significance. It was calculated that water productivity was 21.6, 34.27, and 37.30% higher under F_2 compared with F_1, F_3 and F_4, respectively, which clearly indicated the superiority of F_2 treatment. The values of water productivity under F_1,F_2, F_3 and F_4 were 12.50,15.20,11.32 and 11.07 kg m^{-3}showing the fertilizer and water use efficiencies fo the treatments.

Effect of Fertilizer levels with respect to occurrence of scab on potato

Table 4 showed that percentage of scab was ranged from 2.75% to 4%. It was noted 3% inF_1, and 3.5% in F_2, whereas occurrence of scab was recorded 2.75% and 4% in $F_3$and F_4respectively as depicted in table 4.

Discussion

Although an adoption of drip irrigation over conventional irrigation system would benefit farmers in terms of time, inputs, labor and the reduction in cost associated with fertilizer applications would be attained in the region with drip irrigation and fertigation system. In this way, not only big capital will be saved, but contamination of ground waters with nitrate leaching will also be avoided. In the above study, the effect of drip irrigation and fertigation on potato yield, water productivity, tuber sizes and intensity of scab disease were determined. It was noted that under F_2 the potato yield was higher compared to F_1, F_3 and F_4 respectively (Figure 1).The highest tuber yield in F_2 (75% of recommended dose of NPK) may be attributed to dry matter distribution between above ground and tubers during tuber bulking to obtain a higher yield through better fertilizer use efficiency. These results are in accordance with the findings of Kachwayaand Chandel (2015), who obtained the maximum plant height, leaf area, number of leaves and fruit yield at 75% of recommended dose of NPK using drip irrigation. Similar findings were reported by Zotarelli *et al*. (2009) with tomato (*Solanum lycopersicum* L.) under drip fertigation. Shi *et al*. (2012) found that 70% of conventional fertilizer amount applied was suitable for potato production with drip fertigation.

Tuber yield depends on total dry matter and dry matter distribution toward tuber bulking. During tuber bulking, tubers become the dominant sink for carbohydrates and mobile inorganic nutrients (Westermann,1993) to produce approximately 60% of the potato yield (Zheng *et al*., 2008). Therefore, dry matter distribution between tops and tubers during tuber bulking should be coordinated effectively to obtain high tuber yield under appropriate water and fertilizer management (Xia, 2008).Appropriate fertilizer application effectively facilitated growth of

potato plants under suitable soil water conditions, thus promoting accumulation of dry matter in tubers(Wang *et al*., 2013; Zhou *et al*., 2015; Mishra *et al*., 2016).It was clarified that potato tuber sizes S_2 and S_3 under F_2 was comparatively higher than F_1, F_3, and F_4 except S_1(Figure 2).The medium and large sized tubers have good market value. Therefore, the treatment having higher percentage of medium and large size tubers are required. The investigation in above research revealed that the percentage of desirable medium and large sized tubers underF_2 treatment was highest i.e., 84%. The lowest percentage of small sized tubers was also observed in F_2 where it was 16%, whereas19%, 20.50% and 22.25 % were calculated inF_3, F_1 and F_4, respectively. It is worth mentioning that F_2 treatment showed highest values for potato tuber yield as (26852 kg/ha) was as marketable sizes (84%).

The Water productivity was higher under F_2 compared with F_1, F_3 and F_4, respectively, and clearly indicated the superiority of F_2 treatment (Fig. 3).The results were supported by (Bhingrade, 2015) who explained that irrigation system had significant effects on production of tuber yield. The drip irrigation system might have created optimum soil moisture conditions throughout the growth period of potato crop which provided better plant growth and increased its fertilizer use efficiency. Ierna *et al.* (2011) pointed out that moderate fertilizer rate applied by drip fertigation not only ensured high Potato yield, but also improved the efficient utilization of water and fertilizer resources. Similar results for potato with drip fertigation were found in arid areas of Egypt and North China (Badr *et al*., 2012; Zhang *et al*., 2013).It might be due to the improvement of nutrient availability for potato in the root zone using moderate fertilizer dose (Liu *et al*., 2016) and the better uptake of water and nutrients with potato drip fertigation (Ünlü *et al*., 2006).

The marketable tuber yield, appearance and quality of potato crop can be affected by a common potato tuber disease called scab. It can be controlled by managing soil moisture through proper irrigation (Delahaut and Stevenson, 2009).The results (Figure 4) illustrated that occurrence of scab was found 2.75%,3% and 3.5% forF_3, F_1 and F_2 treatment whereas it was 4% in F_4 treatment. Adequate nutrition is generally required to maintain a high level of disease resistance. Huber and Haneklaus (2016) reported that the severity of most diseases can be greatly decreased by proper nutrient management. Such study could provide valuable facts to achieve higher potato production, and water use efficiency and may help in understanding the interplay between water and fertilizers indifferent process of potato growth and yield formation.

Conclusion

The drip irrigation helps to ensure that nutrients are available when potato plants need it most and reduce the amount lost beyond the root zone. It was noted that under F_2 the potato yield was 21.59%, 34.13% and 37.37% higher as compared to F_1, F_3 and F_4, respectively. Similarly, the irrigation water productivity was also higher under $F_2$and clearly indicated the superiority of F_2 treatment. The improvement in drip-fertigated potato yield accompanied by large savings in the amounts of both fertilizer and irrigation water, indicates that this practice is highly effective for fertilization and water-management program for potato production under local conditions. To improve the yield, marketable tuber size, water productivity and cosmetic value of potato, F_2 (75% of recommended dose of fertilizer) treatment could be adopted and fertigation should be the dominant fertilizer application method for this crop under drip irrigation. Drip-fertigation is a potential irrigation and fertilizer management tool for potato production that can improve water productivity and nutrients utilization efficiency.

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Table1. Effect of different fertigation levels on yield of potato

Treatment	Yield (kg ha^{-1})
F_1	22083ab
F_2	26852 a
F_3	20019 ab
F_4	19547 b

F_1 (100% recommended dose of NPK fertilizer), F_2 (75% recommended dose of NPK fertilizer), F_3 (50% recommended dose of NPK fertilizer) and F_4 (25% recommended dose of NPK fertilizer) In a column, different letters indicate significant differences among fertilizer levels at 5% level by LSD.

Table 2. Effect of different fertilizers levels on sizes of potato tubers

Treatment	Percentage of Potato Tuber Sizes		
	S_1 (small > 35 mm)	S_2 (Medium 35-55 mm)	S_3 (Large < 55 mm)
F_1	20.50	67.25	12.25
F_2	16.00	69.25	14.75
F_3	19.00	68.75	12.25
F_4	22.25	66.00	13.75

F_1 (100% recommended dose of NPK fertilizer), F_2 (75% recommended dose of NPK fertilizer), F_3 (50% recommended dose of NPK fertilizer) and F_4 (25% recommended dose of NPK fertilizer). Tubers sizes S_1 (small, > 35 mm in diameter), S_2 (medium, 35-55 mm in diameter and S_3 (large < 55 mm in diameter).

Table 3. Effect of different fertilizer levels with respect to water productivity

Treatment	Water Productivity (kg m^{-3})
F_1	12.50ab
F_2	15.20a
F_3	11.32ab
F_4	11.07b

F_1 (100% recommended dose of NPK fertilizer), F_2 (75% recommended dose of NPK fertilizer), F_3 (50% recommended dose of NPK fertilizer) and F_4 (25% recommended dose of NPK fertilizer).In a column, different letters indicate significant differences among fertilizer levels at 5% level by LSD.

Table 4. Effect of different fertilizers levels with respect to occurrence of Scab diseases

Treatment	Occurrence of Scab percentage
F_1	3.00
F_2	3.50
F_3	2.75
F_4	4.00

F_1 (100% recommended dose of NPK fertilizer), F_2 (75% recommended dose of NPK fertilizer), F_3 (50% recommended dose of NPK fertilizer) and F_4 (25% recommended dose of NPK fertilizer).

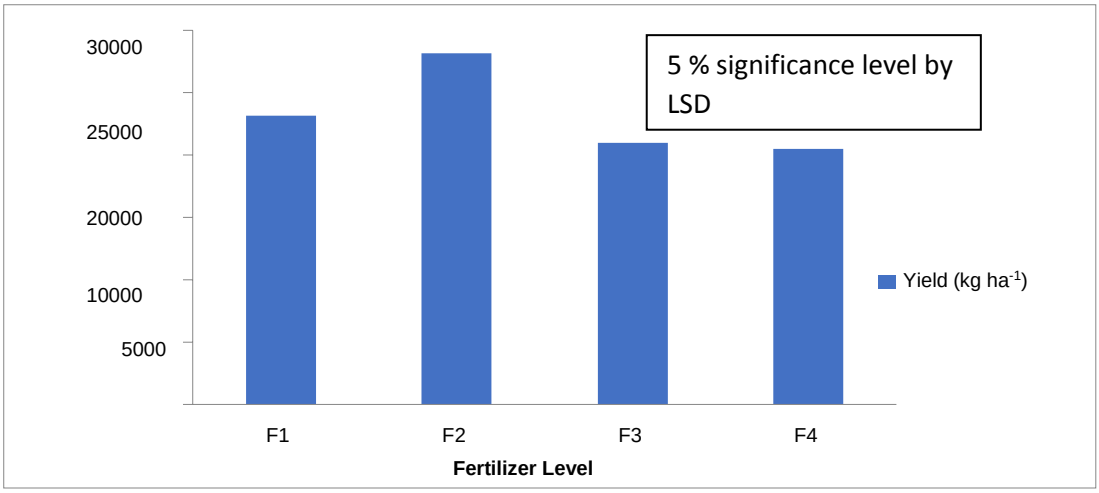

Figure 1. Effect of different fertigation levels on yield of potato

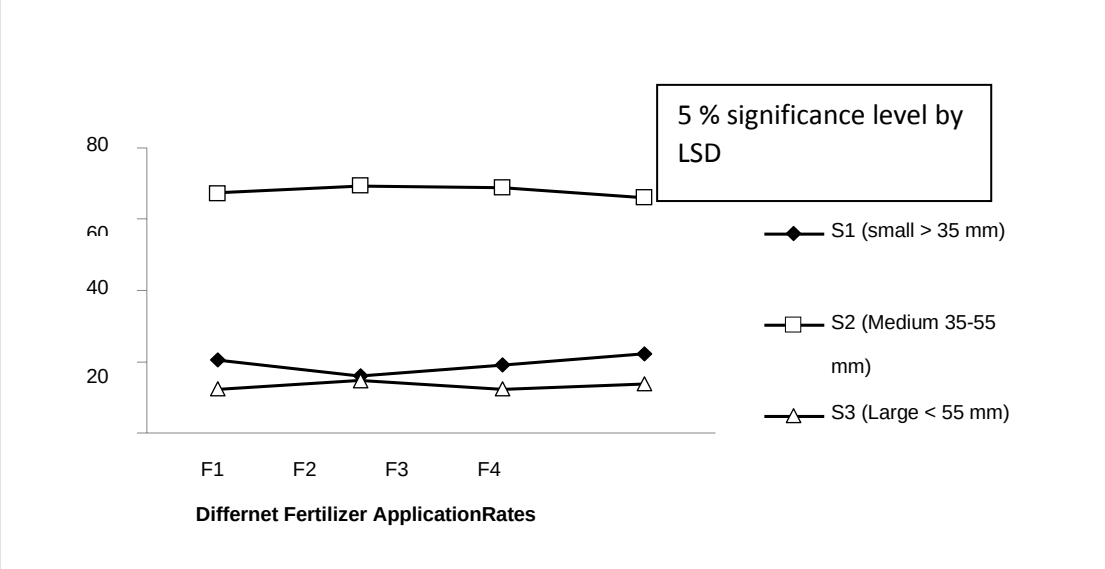

Figure 2. Effect of different fertilizer levels on sizes of potato

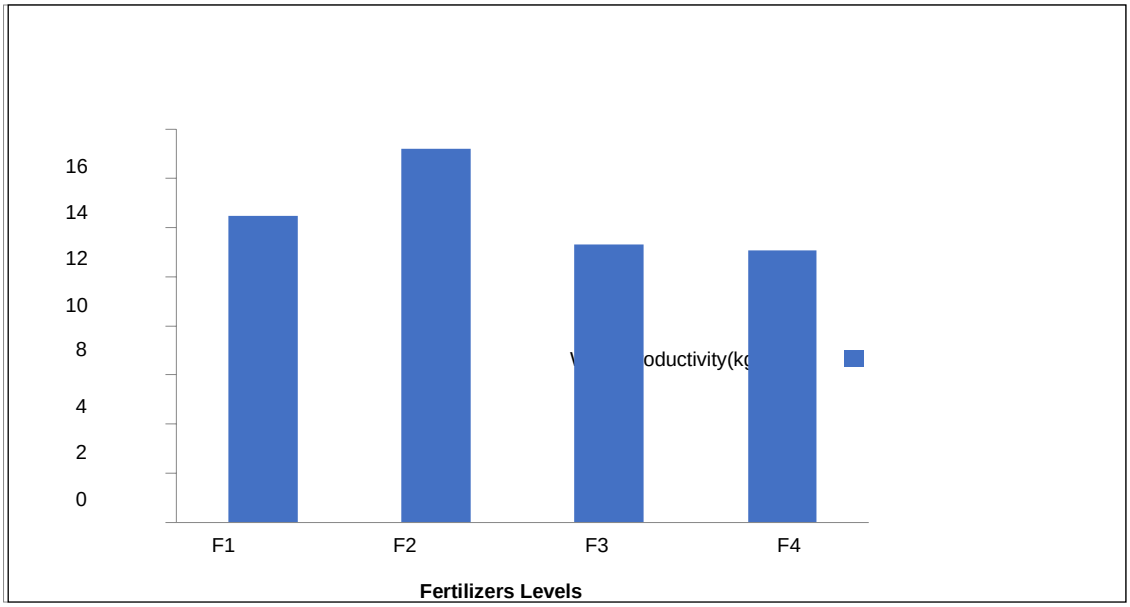

Figure 3. Effect of different fertilizer levels with respect to water productivity

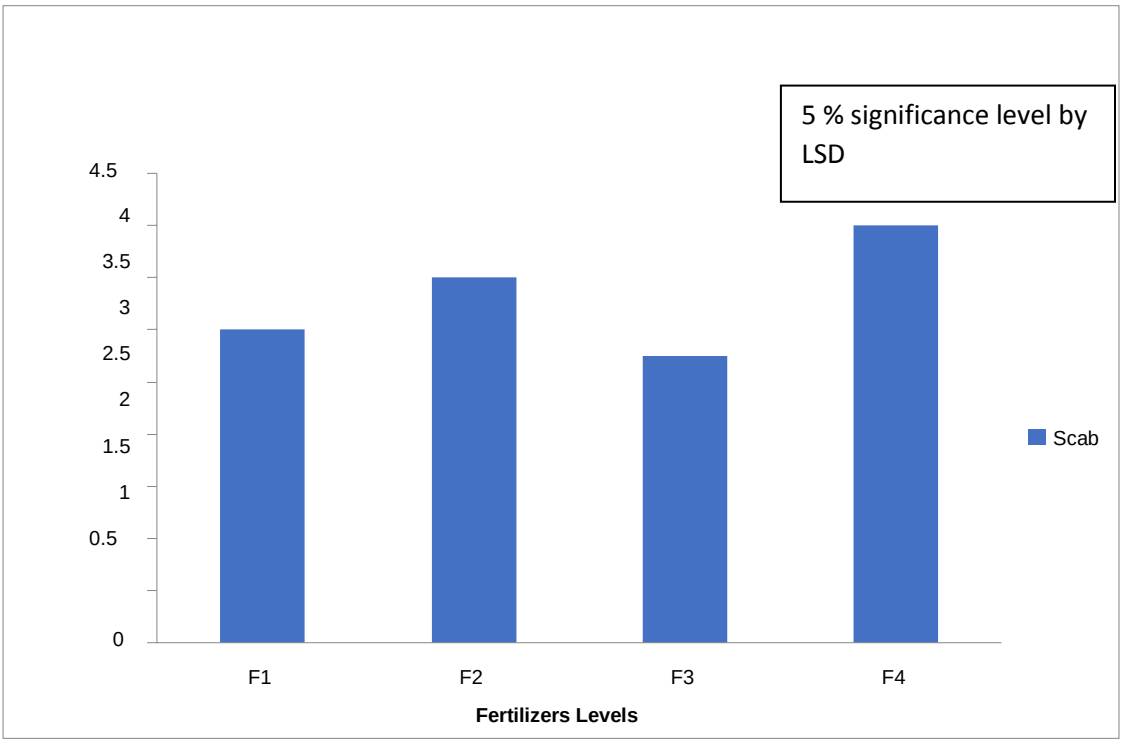

Figure 4. Effect of different fertilizer levels with respect to occurrence of Scab disease