Research Article

Effect of Different Nitrogen Doses and Deficit Irrigation on Nitrogen use Efficiency and Growth Parameters of Tomato Crop under Drip Irrigation System

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Abstract | Tomato is one of the most demanding crops in terms of water and fertilizer inputs. To meet irrigation water demand, growers use surface and ground water resources. These resources are in decline. Realizing the importance of water and fertilizer, tomato yield under deficit irrigation regimes, and different Nitrogen (N) levels were studied during 2015 and 2016 at the research farm of the University of Agriculture Peshawar, Pakistan, using factorial arrangement of randomized complete block design (RCBD). These factors were four irrigation levels; full irrigation (I_0), 15% deficit (I_{15}), 30% deficit (I_{30}) and 45% deficit (I_{45}); and four nitrogen doses;100% of recommended dose (120 kg ha^{-1}) (N_{100}), 85% of recommended dose (N_{85}), 70% of recommended dose (N_{70}) and 55% of recommended dose (N_{55}). I_o was based on 30% of management allowed deficit. Effect of Nitrogen doses on Nitrogen use efficiency (NUE) was found to be highly significant and showed an increasing trend of 7, 25 and 68% with reducing Nitrogen doses. However, the effect on dry-to-fresh weight ratio, plant height, days to 50% flowering, were found to be non-significant. Results indicated that deficit irrigation (I_{15}, I_{30} and I_{45}) had significant effect ($P<0.05$) on plant height and NUE. Plant height tends to decrease by 1.3 and 5.5% with deficit irrigation. NUE also decreased by 17, 16 and 24 with deficit irrigation. Compared to I_0, while the effect on dry to fresh weight ratio and days to 50% flowering was found to be non-significant.

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Introduction

Pakistan has one of the best canal systems in the world but still, in its irrigated area the water availability is not ensured (Khan and Khan, 2019). Due to shortages of water resources, sometimes the crops have to survive on the moisture already present in the root zone and occasional rains. As the temperature tends to rise in the summer plants, water demands tends to rise as well, which ultimately results in water stress. Shallow rooted vegetables like tomato, are more susceptible to water stress during early flowering and fruit developmental stage (Edrneadeset al., 1989). Tomato is considered as an important cash crop, indeed it is inelastic demand in Pakistan (Lohano and Mari, 2005). Tomato requires 400-600 mm of water, management allowed deficit of 30% beyond this point yield reduction starts. Crop Coefficient (Kc) value for tomato during its growing season is 0.7 at the beginning of the growing season, 1.05 during mid-season and 0.8 at the end. Similarly, yield response factor (Ky) value ranges from 0.24 to 0.75 (Khan and Khan, 2019).

In the current irrigation scenarios, the field application efficiency is around 50%, which is very low, and the fertilizer use efficiency of the crop is around 33%, which is also on the lower side (Raun and Jhonson, 1999). Nitrogen in the form of nitrate is highly mobile amongst all the plants nutrients and its availability to the crop is usually limited due to its various pathways by which it is lost to the atmosphere or percolate deeply beyond the root zone. These various pathways are leaching, ammonia volatilization and de-nitrification. Due to these losses, the N efficiency decreases considerably. Nitrogen use efficiency is approximately 33% worldwide; the remaining is a loss, which is considerable loss to the farmers (Singandhupe et al., 2003). Compared to basin irrigation of tomato, drip irrigation is a best option for reducing losses due to deep percolation and evaporation and provides water directly to the plant rootzone. Similar is the case with fertilizer; with fertigation system, nutrients can be provided directly to the rootzone, which is good for enhancing the fertilizer use efficiency. In fertigation fertilizer is first dissolved in water and then applied directly to the plant rootzone. Fertigation technique can be used for fertilizer application to all crops, but it is mainly used for cash crops (Khan and Khan, 2019). Despite producing a high yeild to the farmers, tomato is considered the most input demanding crops in terms of fertilizer, water, and labor (Mari et al., 2007). Therefore, multi-year field trails are suggested to evaluate the impact of deficit irrigation strategies and Nitrogen doses on NUE (Patane et al., 2011).

Keeping in view the prevailing water shortage and poor economic conditions of the local farmers, who are still using basin irrigation and recommended Nitrogen doses for tomato cultivation, the current study was planned on using drip irrigation as it requires less water compared to basin irrigation and has high application efficiency of around 90%. In addition, NUE was also studied under water stress and different Nitrogen levels and almost no data is available on the combined influence of water stress and different Nitrogen doses on NUE. Nitrogen was applied using fertigation technique, which can increase Nitrogen use efficiency and farmers' income.

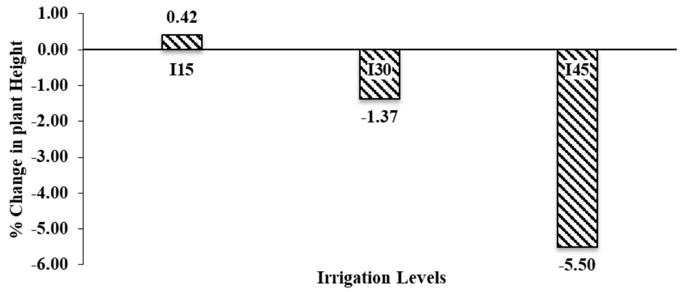

Figure 1: *Relative change in plant height under deficit irrigation compared to full irrigation.*

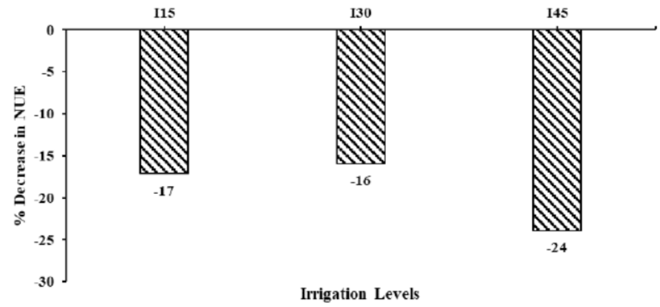

Figure 2: *Relative decrease in NUE under deficit irrigation compared to full irrigation.*

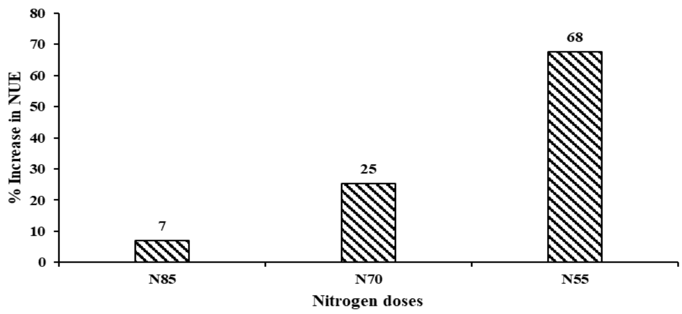

Figure 3: *Relative increase in NUE under different nitrogen doses compared to recommended nitrogen dose.*

Materials and Methods

Description of the study area

The study was conducted at the Research Farm of the University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan, having similar agroclimatic conditions to that of the tomato growing area in Peshawar. The research farm is located at 34.02 °N and 71.46 °E with an altitude of 331m. The experiments were conducted during growing season of tomato (March to June 2015 and 2016). Peshawar lies in semi-arid subtropical region with warm to hot climatic condition. Climatic conditions like temperature and rainfall are presented in Figures 4 and 5 respectively.

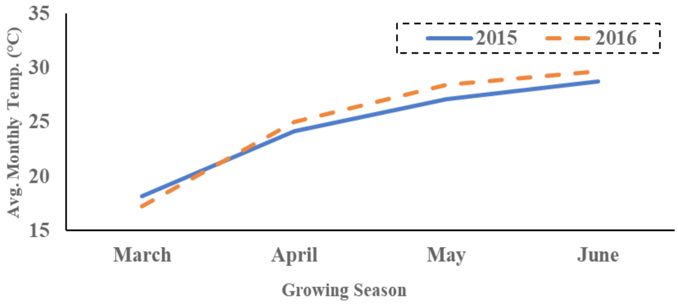

Figure 4: *Average monthly temperature of the study area during the growing season of Tomato in 2015-16.*

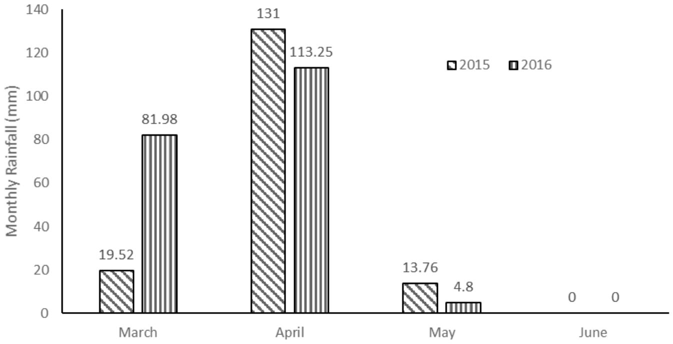

Figure 5: *Monthly rainfall of the study area during the growing season of Tomato in 2015-16.*

Table 1: *Effect of deficit irrigation and nitrogen doses on tomato fresh to dry weight ratio.*

Irrigation (I)	Nitrogen (N)	Year		Average
		2015	2016	
I_0	N_{100}	0.85	0.73	0.79
	N_{85}	0.84	0.79	0.82
	N_{70}	0.90	0.79	0.84
	N_{55}	0.82	0.69	0.76
I_{15}	N_{100}	0.87	0.81	0.84
	N_{85}	0.84	0.80	0.82
	N_{70}	0.85	0.76	0.81
	N_{55}	0.85	0.79	0.82
I_{30}	N_{100}	0.90	0.75	0.83
	N_{85}	0.89	0.77	0.83
	N_{70}	0.87	0.83	0.85
	N_{55}	0.88	0.76	0.82
I_{45}	N_{100}	0.86	0.78	0.82
	N_{85}	0.84	0.82	0.83
	N_{70}	0.86	0.82	0.84
	N_{55}	0.85	0.76	0.81
I_0		0.85	0.75	0.80
I_{15}		0.86	0.79	0.82
I_{30}		0.89	0.78	0.83
I_{45}		0.85	0.80	0.82
	N_{100}	0.87	0.77	0.82
	N_{85}	0.85	0.79	0.82
	N_{70}	0.87	0.80	0.83
	N_{55}	0.85	0.75	0.80
		0.86	0.78	

Experimental details

The experiment was arranged in a randomized complete block design (RCBD) with four irrigations levels (0, 15, 30 and 45% Deficit) based on 30 MAD applied through drip irrigation and four different doses of N (100, 85, 70 and 55% of recommended dose of 120 kg ha^{-1}) applied through fertigation technique. Plant to plant spacing was 40 cm and row to row spacing was 60 cm. I_0 and N_{100} were taken as control. Tomato variety Syngenta T1359 was used because of its viral resistivity and popularity amongst the local farmers.

Plant height (cm)

From each treatment 3 plants were randomly selected in head middle and tail of the lateral and plant height was recorded in cm at 15 days interval till harvesting.

Days to 50 % flowering

After transplantation, days to 50 % flowering was regularly monitored by counting the number of plants with flowers, when 50% of the plants bearing flowers then the data were recorded.

Dry to fresh weight ratio

Three plant from each treatment were randomly selected and were used for determination of fresh and dry shoot weight after 25 days of transplanting. Fresh weight was measured in the field with the help of balance and then plants were brought to the laboratory where they were put in the oven for three days at 80 °C so that they become completely dry after that dry weight was measured and dry to fresh (DF) weight ratio was calculated by the following equation.

$$\text{Dry to Fresh weight Ratio} = \frac{Fw - Dw}{Fw} \quad \ldots (3.7)$$

Where;

Fw = Fresh Weight; Dw = Dry Weight.

Nitrogen use efficiency

Nitrogen use efficiency (NUE) of tomato was calculated using the following equation outlined by (Khan and Khan, 2019).

$$NUE = \frac{\text{Crop Yield}}{\text{Total Nitrogen Applied}} \quad \ldots (3.10)$$

Statistical analysis

The experiment was conducted in a randomized complete block design. The data was analyzed using two-way ANOVA and the mean comparisons was made using LSD test (Steel and Torie, 1984).

Results and Discussion

Plant height and Nitrogen use efficiency were significantly affected by deficit irrigation. Figure 1 shows that I_{15} has 0.42% higher plant height compared to I_0, while I_{30} and I_{45} had 1.3 and 5.5% lower plant height compared to I_0. The reason for this decrease in plant height due to deficit irrigation might be lower moisture availability for N mobilization, resulting in decreased vegetative growth and shorter plants (Yuan et al., 2003). Another reason of decreased plant height may be due to deficit irrigation because in water stress condition the plant extends its rooting depth in search of water and for compensation of this extension the plant height is suppressed resulting in shorter plants (Brahma et al., 2007). Figure 2 shows that $I_{15,}$ I_{30} and I_{45} had 17, 16 and 24% lower Nitrogen Use efficiency compared to I_0. The results of NUE are in close conformation with Du et al. (2017) who reported that NUE increase with increasing irrigation levels. Whereas days to 50% flowering and dry to fresh weight ration were affected non-significantly (Table 1). This might be due to the fact that deficit irrigation promotes early flowering. Hueso et al. (2004) also reported that increasing deficit irrigation promotes early flowering in tomato compared to full irrigation. Maskri et al. (2010), also reported that plant dry to fresh weight ratio was non-significantly affected by deficit irrigation.

Nitrogen doses had non-significant effect on plant height, days to 50% flowering and dry to fresh to fresh weight ratio. The reason for non-significant effect of Nitrogen doses might be high temperature (average temperature above 30 °C) and low humidity during plant growth, that impeded the impact of increasing Nitrogen doses on plant height. This indicates that this parameter depended on the genetic potential of the tomato cultivar. Nitrogen application time and doses had non-significant effect on plant height (Filho et al., 2011). In days to 50% the non-significant effect might be due to the fact that when plants are unable to find the required Nitrogen for their vegetative growth they are forced to reproductive growth. While for non-significant effect of Nitrogen doses on dry to fresh weight ratio the reason might be that water potential for all the N treatments remained constant and hence equal amount of water was taken up by plants. Another reason might be that leaf osmotic potential decreases with increasing Nitrogen doses (Grada et al., 2000). Nitrogen doses had significantly increased NUE. Figure 3 shows an increase of 7, 25 and 68 for N_{85}, N_{70} and N_{55}, respectively, compared to N_{100}. These results are in close conformation with Du et al. (2017) who reported that NUE decreases with increasing Nitrogen doses.

Conclusions and Recommendations

From the results it is evident that deficit irrigation significantly affects growth parameters and NUE in tomato crop whereas the response of tomato towards Nitrogen doses was non-significant therefore for better growth of tomato crop, deficit irrigation is not recommended.

Novelty Statement

Importance of this research is the Nitrogen Use Efficiency (NUE). Farmers will significantly save water and fertilizer for tomato yield under deficit irrigation regimes.

Author's Contribution

Masaud Khan: Principal author, did research and field experiments.
Muhammad Jamal Khan: Major supervisor who provided technical guidelines.
Shahab Ahmad: Helped in data collection.
Asad Ali: Helped in field work.
Numan Khan: Helped in material collection.
Muhammad Adnan Fahad: Helped in technical write up.

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