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NPK Uptake of Tomato as Influenced by Irrigation Regimes and Fertigation Levels under Greenhouse Condition

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KAE, MSB and HTC designed the study, wrote the protocol, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Authors MVM, YBP, BMR and PLP contributed to the protocol writing and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in two seasons during 2012-2013 at Hi-Tech-Horticulture unit, Saidapur, UAS, Dharwad, Karnataka, India to evaluate the effect of drip irrigation and fertigation levels on NPK uptake of tomato hybrid STH-801 under greenhouse conditions. The experiment was laid out with three drip irrigation regimes (I_1 = 40, I_2 = 60 and I_3 = 80% of crop evapotranspiration; ETc) and three fertigation levels (F_1 = 50, F_2 = 75 and F_3 = 100% of

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recommended dose of fertilizers; RDF) in randomized complete block design (RCBD) with factorial concept and replicated thrice with one absolute control. The results showed that NPK uptake by plants was significantly enhanced by irrigation regimes, fertigation levels and their interaction at fruiting and harvesting stage. However, non-significant difference was recorded in nutrients uptake at flowering stage. Irrigation regime at 40% ETc showed a significant reduction in NPK uptake by plants as compared to I_2 and I_3 irrigation regimes. However, no significant difference was recorded in nutrients uptake between I_2 and I_3. The effect of fertigation levels on nutrients uptake was also significant at fruiting and harvesting stage. The uptake of NPK by plant was significantly higher at F_2 and F_3 than at F_1. However, there was no significant difference in nutrients uptake between F_2 and F_3. Fertigation treatments recorded significantly higher nutrients uptake as compared to conventional soil application of normal fertilizers with drip irrigation.

Keywords: Polyhouse; fertigation; drip irrigation; water stress; nutrient uptake.

1. INTRODUCTION

Greenhouse farming, also known as protected cultivation, is one of the farming systems widely used to provide and maintain a controlled environment suitable for optimum crop production leading to maximum profits. This includes creating an environment suitable for working efficiency as well as for better crop growth. Greenhouses protect the crop from varied climatic conditions like wind, rainfall, excess solar radiation, extreme temperature conditions and also incidence of pests and diseases. Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crop next to potato throughout the world and grown in a wide range of climatic conditions.

Fertilization and irrigation are important management practices to improve crop productivity. Compared to cereal production, vegetable cultivation often requires more intensive management and larger amounts of fertilizers and irrigation water [1]. The overgrowing world population and recent droughts are putting water resources under pressure and calling for new approaches for water planning and management. Irrigation is the major consumer of diverted water from surface and groundwater in the world. Therefore, it must be carried with high efficiency. One pre-requisite for efficient irrigation is knowledge of consumptive use of major crops or their evapotranspiration characteristics. Such information is required to minimize percolation losses, runoff and thus environmental pollution [2]. Studies carried out across different countries including India have confirmed that irrigation plays a paramount role in increasing the yield and enhancing cropping intensity as well as their productivity [3]. A correct determination of irrigation scheduling is one of the main factors in achieving high yields and avoiding loss of quality in greenhouse tomato [4].

Over-fertilization of greenhouse vegetables resulted in nutrients accumulation, acidification and salinity of soils and groundwater contamination [1], as well as a negative impact on soil microbial diversity and enzyme activity [5]. Excessive fertilization of greenhouse lands contributes to accelerating groundwater contamination. Therefore, nitrate leaching losses from intensive vegetable systems has been identified as a major source of nitrate pollution in groundwater systems [6]. In addition, use of low water inputs and fertilizer with high nutrient use efficiency is one of the methods used in addressing the environmental and resource problems [7].

Under drip irrigation only a small portion of soil volume around each plant is wetted, so crop root growth is essentially restricted to this wetted volume of soil and nutrients within that volume are subject to accelerated crop uptake. The better performance under drip has been attributed to maintenance of favorable soil water conditions in the root zone, which in turn helped the plants to utilize water and nutrients more efficiently from the wetted area [8]. In a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled. The availability of nutrients evenly with frequent fertigation was responsible for the improvement of nutrient uptake and recovery in the root zone coupled with reduced loss of nutrients primarily because of less leaching under higher fertigation rates [9].

The main objective of this experiment was to evaluate the effect of drip irrigation and fertigation levels on the uptake of nitrogen, phosphorus and potassium by tomato at different growth stages under greenhouse conditions.

2. MATERIALS AND METHODS

2.1 Site Characteristics

Field experiments were conducted in two seasons during 2012-2013 in a natural ventilated polyhouse at Hi-Tech-Horticulture unit, Agricultural Research Station, Saidapur, UAS, Dharwad, Karnataka, India. Dharwad is geographically located on latitude 15°-26' N and longitude 75°-7' E at an altitude of 678 m above sea level. The soil of the experimental plot is of sandy loam texture with a pH of 7.3 and EC of 1.75 dSm^{-1}, low in available nitrogen (240 kg ha^{-1}), medium in available phosphorus (24 kg ha^{-1}) and high in available potassium (311 kg ha^{-1}). The recommended dose of fertilizers (RDF) for tomato hybrid STH-801 is 250:250:250 kg N, P_2O_5 and K_2O per ha and 38 tonnes farmyard manure (FYM) per ha as per cultivation practices.

2.2 Experimental Treatments and Design

Three drip irrigation regimes (I_1= 40%, I_2= 60% and I_3= 80% of ETc) were based on accumulated pan evaporation (E_{pan}) and three fertigation levels (F_1= 50%, F_2= 75% and F_3= 100% of RDF) in the form of water soluble fertilizer were laid out in factorial randomized complete block design with 9 treatment combinations and replicated three times with one absolute control (drip irrigation at 100%- ETc and soil application of 100% RDF in the form of conventional fertilizer).

During the initial growth stage, all the experimental plots received equal amount of irrigation water (100% ETc) to ensure proper establishment of the tomato plants. Thereafter, water was applied according to drip irrigation regimes at 2 days irrigation interval. Seasonal irrigation water (IW) for different irrigation regimes during the two seasons are presented in Fig. 1.

For fertigation treatments 20% RDF (conventional fertilizers) + 38 tons of FYM per ha was applied as basal dose. The remaining RDF for F_1 fertigation level 30% (75:75:75 N, P_2O_5 and K_2O kg per ha), F_2 55% (137.5:137.5:137.5 N, P_2O_5 and K_2O kg per ha) and F_3 80% (200:200:200 N, P_2O_5 and K_2O kg per ha) were applied in the form of water soluble fertilizer in equal doses for 16 times (15 DAP to 120 DAP). However, in the control treatment 50, 100 and 100% of N, P_2O_5 and K_2O of recommended dose in the form of conventional fertilizers along with 38 tons FYM per ha were applied as basal dose. The remaining 50% of N was applied in 2 splits (30 and 60 DAP).

2.3 Experimental Procedure

The experiment was carried out in a naturally ventilated polyhouse (NVP) with a size of 28 m long, 20 m wide with central height of 6 m. Drip irrigation system was installed for the complete cropped area. Land area inside the NVP was thoroughly dug to a depth of 30 cm. The land was incorporated with farmyard manure, urea, diammonium phosphate, muriate of potash also applied as basal dose. Raised beds of 30 cm high and 100 cm wide to a length of 25 m were prepared with the walking space between beds. At the centre of the bed, two inline dripper laterals were placed. The inline dripper lateral had an emitting point for every 30 cm interval with a discharge of 2 lit/hour. Paired row system of planting in a zigzag pattern was employed to ensure improved aeration among the plants. A distance of 50 cm between the rows and 60 cm between plants in the row was employed as the planting distance. Raised beds of 30 cm high and 1 m wide was prepared with 50 cm gap between beds. Tomato seedlings were transplanted at 22 day old on 29th September 2012 and 7th April 2013 for first and second season, respectively. Fruits were harvested at colour breaking stage. Harvesting of tomato fruits started at 90 days after transplanting and continued till 172 and 180 days after transplanting for first and second seasons, respectively.

Whole plant samples were collected from all the plots at critical stages of crop growth for chemical analysis. These samples were oven dried at 70°C till constant weight was recorded. The samples were ground in a Willey mill and preserved in butter paper bags. The uptake of nitrogen, phosphorus and potassium by plants were determined using micro Kjeldahl, vanadomolybdate yellow colour and flame photometric methods, respectively.

3. RESULTS

3.1 Nitrogen Uptake

At flowering stage, the effect of irrigation regimes, fertigation levels and their interaction was not significant on N uptake (Fig. 2). Similarly, all fertigation treatments did not significantly influence N uptake at flowering stage as compared to the control.

However, at fruiting stage, I_3 (80% ETc) recorded the highest N uptake (100.35 and 88.21 kg N ha^{-1} in the first and second seasons, respectively) followed by I_2 (60% ETc) (98.78 and 85.87 kg N ha^{-1} in the first and second seasons, respectively). However, they were at par and significantly superior to I_1 (40% ETc) which recorded the lowest N uptake (77.82 and 66.30 kg N ha-1 in the first and second seasons, respectively). Similarly, at harvesting stage,

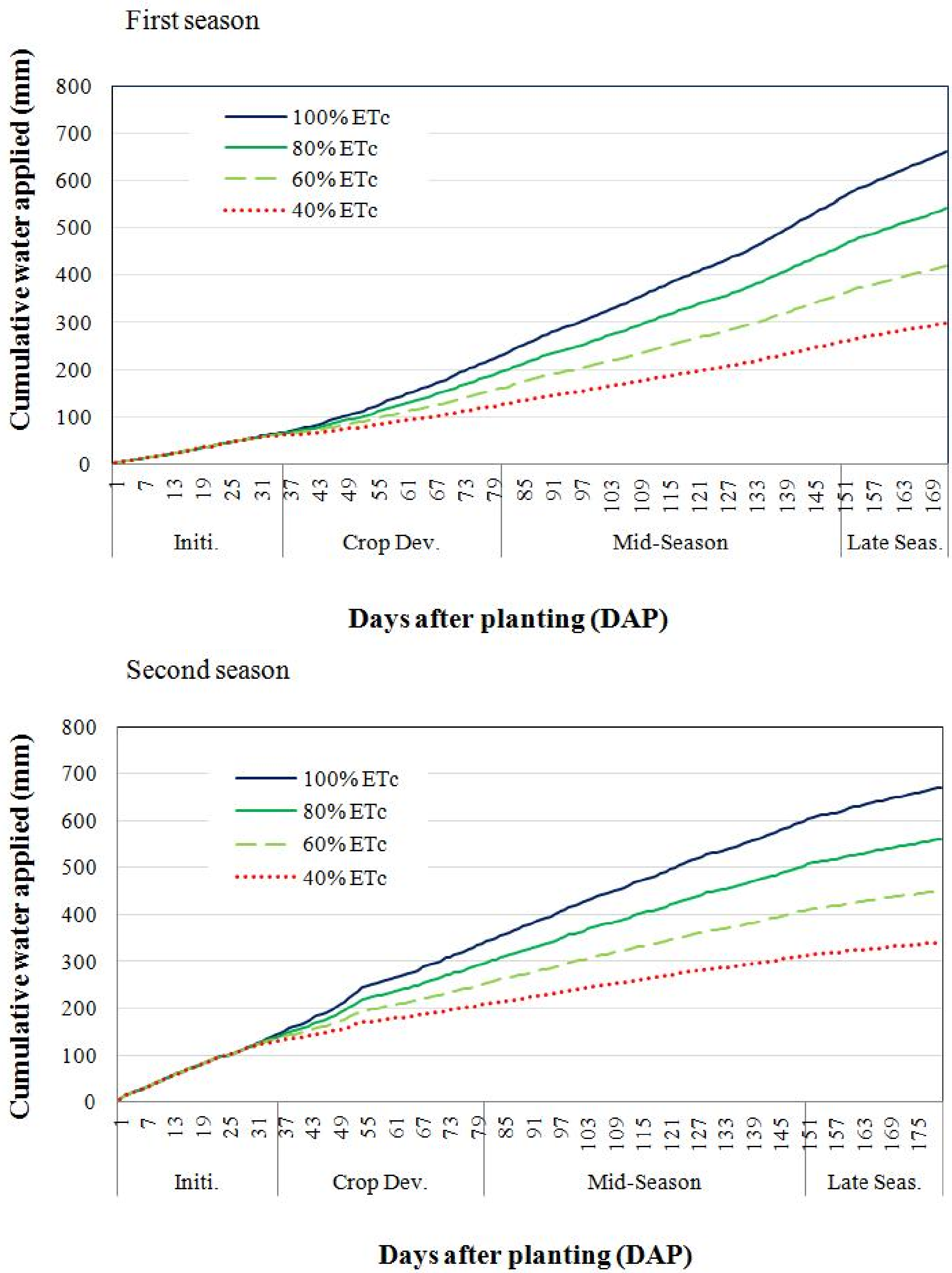


Fig. 1. Cumulative water applied (mm) to tomato for different irrigation regimes during the two seasons

the irrigation regimes showed significant effect on N uptake by the plants. The maximum N uptake (137.64 and 124.84 kg N ha^{-1} in the first and second seasons, respectively) was recorded with I_2 which was at par with I_3 (136.62 and 124.43 kg N ha^{-1} in the first and second seasons, respectively). However, irrigation at I_1 (40% ETc) recorded significantly lower N uptake (117.26 and 104.16 kg N ha^{-1} in the first and second seasons, respectively) as compared to I_2 and I_3 irrigation regimes.

Irrespective of irrigation regimes, the effect of fertigation levels on N uptake was also significant at fruiting and harvesting stages. Fertigation at 100% RDF (F_3) recorded the highest N uptake (99.46 and 85.89 kg N ha^{-1} in the first and second seasons, respectively) at fruiting stage which was at par with F_2 (75% RDF) (98.52 and 84.24 kg N ha^{-1} in the first and second seasons, respectively). However, fertigation at F_1 (50% RDF) registered significantly lower N uptake (78.96 and 70.26 kg N ha^{-1} in the first and second seasons, respectively) at fruiting stage as compared to other fertigation regimes. The N uptake also decreased significantly under low fertigation level treatments (50% RDF) at harvesting stage. Application of 100% RDF through fertigation (F_3) recorded the highest N uptake (135.28 and 122.32 kg N ha^{-1} in the first and second seasons, respectively) at harvesting stage which was at par with F_2 (133.99 and 121.80 kg N ha^{-1} in the first and second seasons, respectively) and significantly lowest N uptake (122.25 and 109.30 kg N ha^{-1} in the first and second seasons, respectively) was recorded with F_1.

Likewise, interaction effect between irrigation regimes and fertigation levels was also significant with respect to N uptake at fruiting and harvesting stages. The treatment combinations I_2F_2, I_2F_3, I_3F_2 and I_3F_3 recorded higher N uptake, which were at par and significantly superior to the rest of the fertigation treatments and control.

3.2 Phosphorus Uptake

At flowering stage, irrigation regimes, fertigation levels and interaction did not influence significantly on P uptake (Fig. 3). Similarly, fertigation treatments did not differ significantly with respect to P uptake at flowering stage as compared to the control.

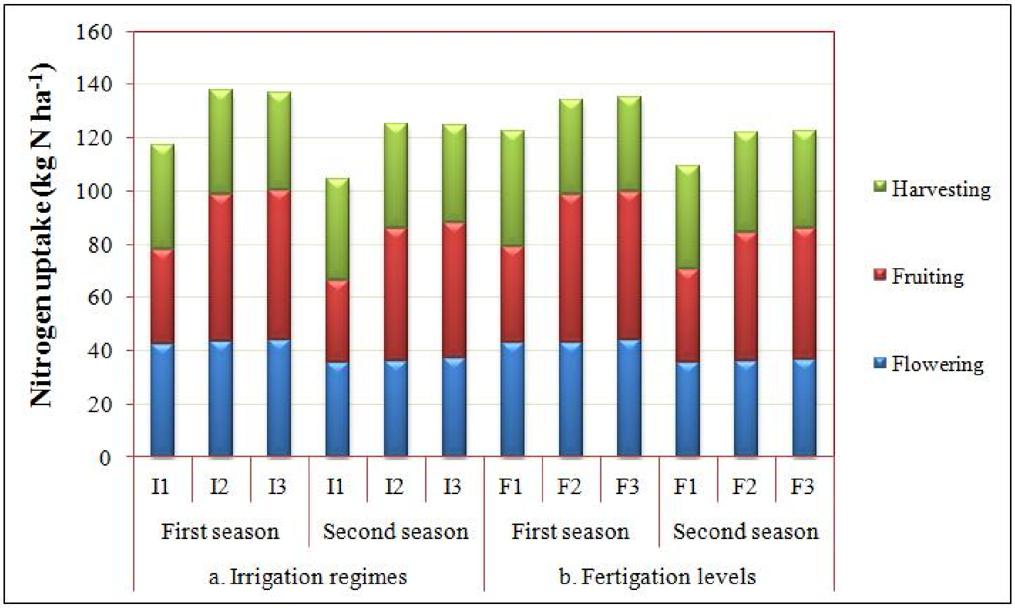
At fruiting stage, P uptake was significantly influenced by irrigation regimes. Application of 80% ETc (I_3) recorded the highest P uptake (12.84 and 11.07 kg P ha^{-1} in the first and second seasons, respectively) at fruiting stage which was at par with I_2 (12.66 and 10.79 kg P ha^{-1} in the first and second seasons, respectively). However, irrigation at I_1 recorded significantly lower P uptake (9.47 and 7.49 kg P ha^{-1} in the first and second seasons, respectively) at fruiting stage as compared to the rest of irrigation regimes. Similarly, at harvesting stage, the effect of irrigation regimes on P uptake was also significant. Irrigation at I_{2-} recorded the highest P uptake (23.42 and 20.32 kg P ha^{-1} in the first and second seasons, respectively) which was at par with I_3 (23.31 and 20.15 kg P ha^{-1} in the first and second seasons, respectively). However, I_1 recorded significantly lower P uptake (19.68 and 16.85 kg P ha^{-1} in the first and second seasons, respectively) as compared to the rest of the irrigation regimes.

The fertigation levels showed also significant influenced on P uptake at fruiting and harvesting stages. At fruiting stage, F_3 registered the highest P uptake (12.74 and 10.82 kg P ha^{-1} in the first and second seasons, respectively) which was at par with F_2 (12.62 and 10.60 kg P ha^{-1} in the first and second seasons, respectively). However, significantly the lowest P uptake (9.61 and 7.94 kg P ha^{-1} in the first and second seasons, respectively) was registered with fertigation at F_1. Likewise, at harvesting stage, fertigation at F_3 recorded the highest P uptake (23.57 and 20.08 kg P ha^{-1} in the first and second seasons, respectively) which was at par with F_2 (23.25 and 19.76 kg P ha^{-1} in the first and second seasons, respectively). However, significantly the lowest P uptake (19.59 and 17.49 kg P ha^{-1} in the first and second seasons, respectively) was recorded by F_1.

Interaction effect between irrigation regimes and fertigation levels also differed significantly with respect to P uptake at fruiting and harvesting stages. Higher P uptake was recorded with the treatment combination of I_2F_2, I_2F_3, I_3F_2 and I_3F_3, which were at par and significantly superior over the rest of the fertigation treatments and control.

3.3 Potassium Uptake

At flowering stage, K uptake did not significantly differ among irrigation regimes and fertigation levels (Fig. 4). Likewise, fertigation treatments did not significantly influence K uptake at flowering stage as compared to the control.



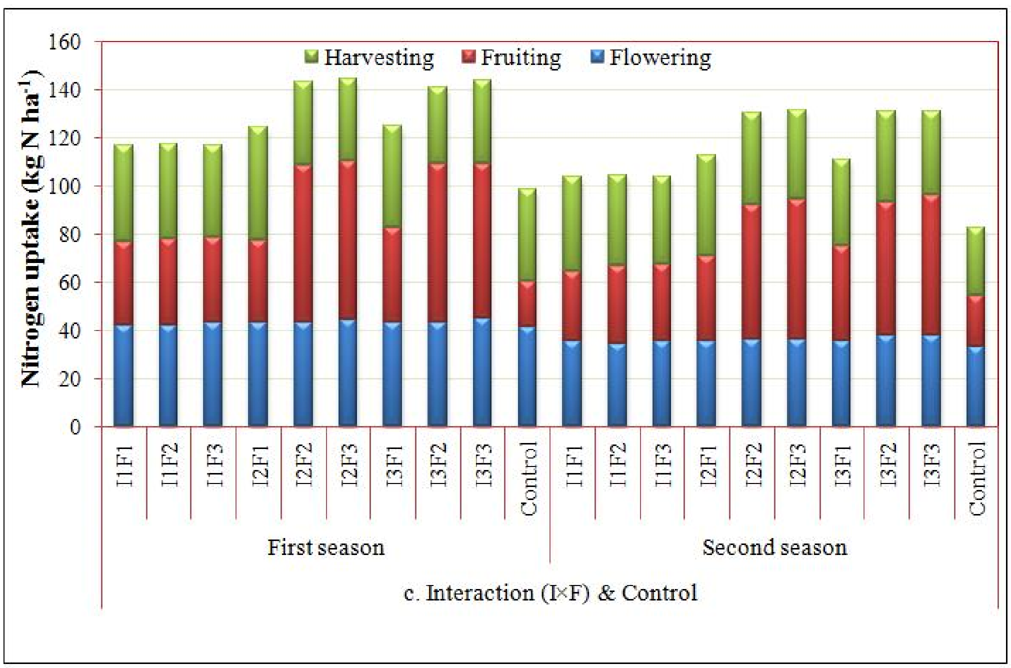
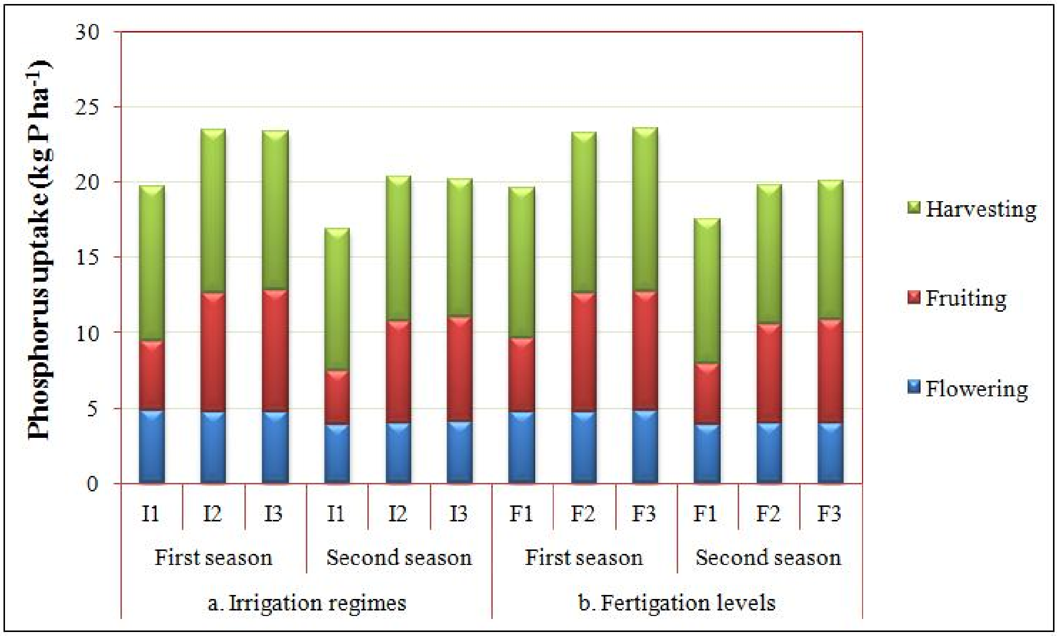


Fig. 2. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on nitrogen uptake (kg N ha^{-1}) at different growth stages of tomato in both seasons

However, at fruiting stage, K uptake was significantly influenced due to irrigation regimes, comparatively higher K uptake (128.21 and 112.24 kg K ha^{-1} in the first and second seasons, respectively) was noticed in I_3, this was followed by I_2 (126.90 and 109.79 kg K ha^{-1} in the first and second seasons, respectively) which were at par and significantly superior to I_1 (96.64 and 80.62 kg K/ha in the first and second seasons, respectively). Similarly, the K uptake differed significantly due to irrigation regimes at harvesting stage. The irrigation regime I_2 has registered highest K uptake (176.89 and 157.38 kg K ha^{-1} in the first and second seasons, respectively), which was at par with I_3 (173.82 and 155.61 kg K ha^{-1} in the first and second seasons, respectively). However, irrigation at I_1 recorded significantly lower K uptake (143.86 and 122.82 kg K ha^{-1} in the first and second seasons, respectively) as compared to the other irrigation regimes.



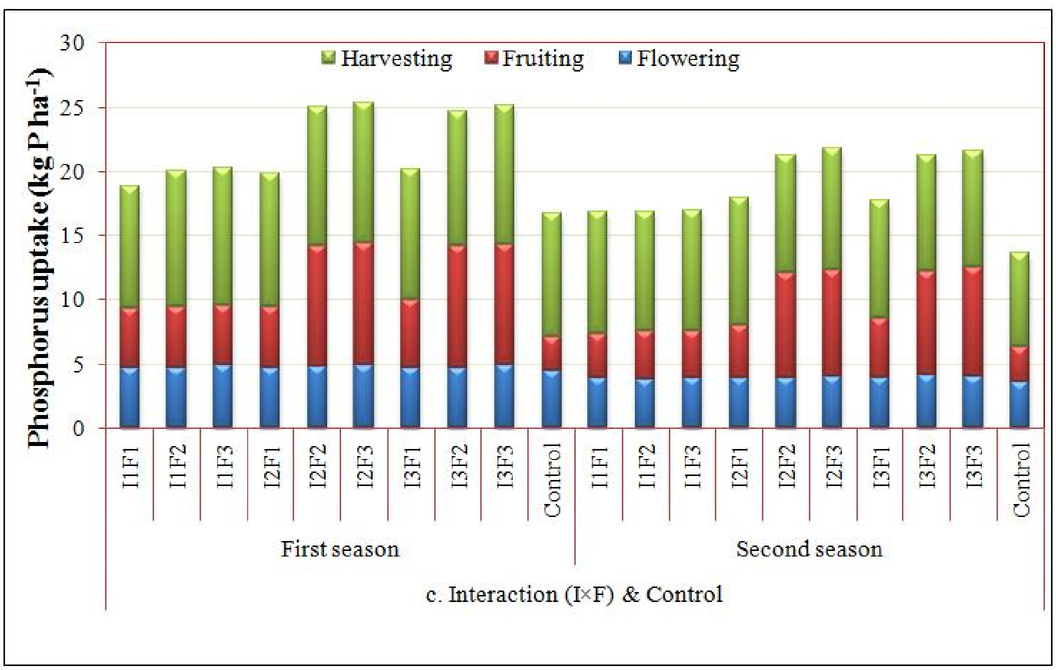
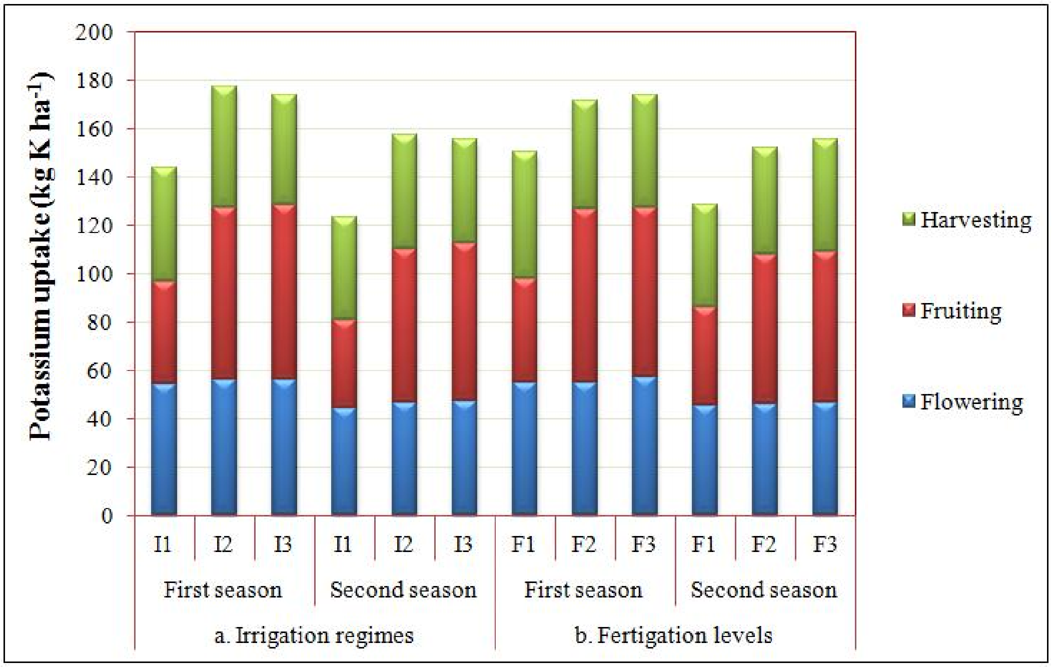


Fig. 3. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on phosphorus uptake (kg P ha^{-1}) at different growth stages of tomato in both seasons



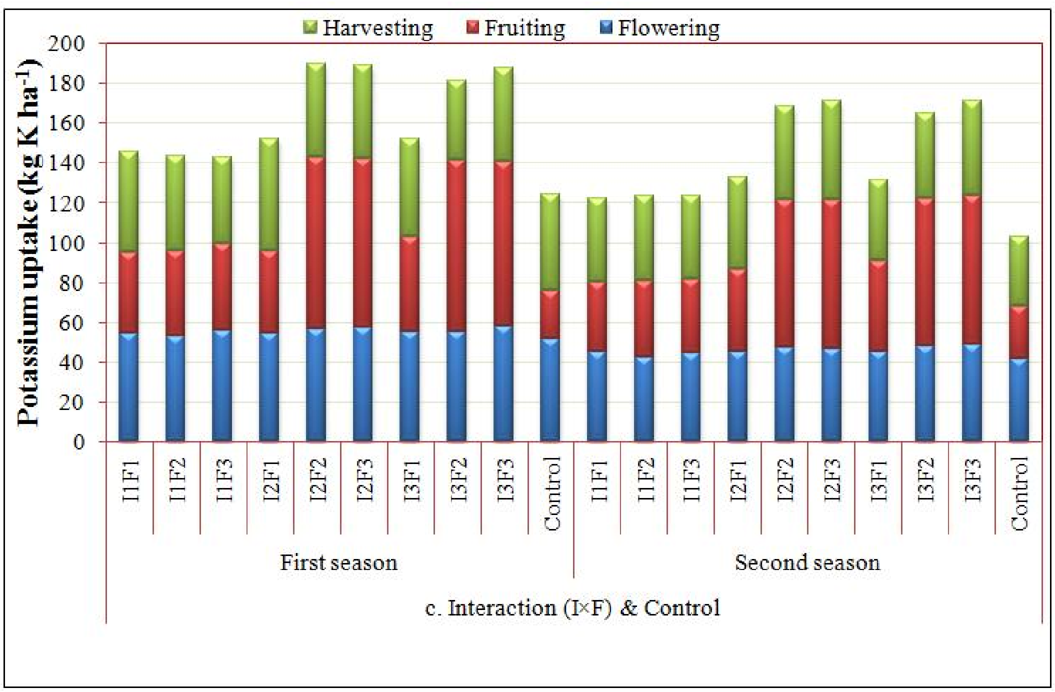


Fig. 4. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on potassium uptake (kg K ha^{-1}) at different growth stages of tomato in both seasons

Data also showed that, there was significant increase in K uptake with the increase in the levels of fertigation dose at fruiting and harvesting stages. F_3 showed highest K uptake (127.36 and 108.93 kg K ha^{-1} in the first and second seasons, respectively) at fruiting stage and this was followed by F_2 (126.60 and 107.99 kg K ha^{-1} in the first and second seasons, respectively) which were at par and significantly superior to F_1 (97.79 and 85.72 kg K ha^{-1} in the first and second seasons, respectively). Likewise, at harvesting stage, the highest K uptake of 173.30 and 155.18 kg K ha^{-1} in the first and second seasons, respectively, was recorded by F_3 and was followed by F_2 with 171.38 and 152.07 kg K ha^{-1} in the first and second seasons, respectively. However, significantly the lowest K uptake was noticed in F_1 with 149.88 and 128.56 kg K ha^{-1} in the first and second seasons, respectively.

The interaction effect between irrigation regimes and fertigation levels were significantly different for K uptake at fruiting and harvesting stages. Significantly higher K uptake was noticed in the treatment combination of I_2F_2, I_2F_3, I_3F_2 and I_3F_3 which were at par and significantly superior to the rest of the fertigation treatments and control.

4. DISCUSSION

Nutrients play a major role in enhancing growth, yield and quality of a crop. Nutrient uptake had positively and significantly higher correlation with yield as evidenced by Li et al. [10]. The uptake of NPK by plants was significantly influenced by irrigation regimes, fertigation levels and their interaction at fruiting and harvesting stages. However, no significant difference was recorded in nutrients uptake at flowering stage. This might be due to the fact that during the initial growth stage (35 DAP), all the experimental plots received equal amount of irrigation water (100% ETc) to ensure proper establishment of tomato plants, thereafter, water was applied according to the specified irrigation regimes, herein referred to as the irrigation treatments.

At fruiting and harvesting stage, the irrigation regimes showed significant retraction on NPK uptake by plant under water stressed treatment I_1 (40% ETc) as compared to I_2 (60% ETc) and I_3 (80% ETc) irrigation regimes. However, no significant difference was recorded in nutrients uptake between I_2 and I_3. The lower growth and dry matter production in I_1 might have contributed to lower nutrients uptake by plant. Also, it is likely that decreased soil water availability reduced nutrients uptake due to decrease in nutrients mobility [11].

The effect of fertigation levels on nutrients uptake revealed that as the rate of NPK application increased, the nutrients uptake also increased. The uptake of NPK by the plants was significantly higher at F_2 (75% RDF) and F_3 (100% RDF) than at F_1 (50% RDF). However, there was no significant difference in nutrients uptake between F_2 and F_3, which indicates a saving of nitrogen to the tune of 25%. This might due to the better availability of nutrients in the crop root zone as a result of frequent application of nutrients coupled with better root activity. Further, it was also due to the reduced loss of nutrients primarily from leaching.

In addition, fertigation treatments recorded significantly higher nutrients uptake as compared to the soil application of conventional fertilizers with drip irrigation. This may due to the synchronization between nutrients uptake by the plants and nutrients availability in the soil in fertigation treatments where fertilizers were applied through 16 split doses to match the nutrients uptake by the crop. The applied NPK in soluble form in fertigation treatments may have been distributed better throughout the crop root zone than the control (soil application of conventional fertilizers) and enhanced the availability of nutrients for plant uptake. The soil application of conventional fertilizers generally tends to cause uneven distribution of fertilizers in the root zone [12].

5. CONCLUSION

Uptake of NPK by tomato was significantly enhanced by irrigation regimes, fertigation levels and their interaction at fruiting and harvesting stages. However, no significant difference was recorded in nutrients uptake at flowering stage. Irrigation regime at 40% ETc resulted in significant reduction in NPK uptake as compared to 60% ETc and 80% ETc irrigation regimes. However, no significant difference was recorded in nutrients uptake between 60% ETc and 80% ETc. The effect of fertigation levels on nutrients uptake was also significant at fruiting and harvesting stages. The uptake of NPK by plant was significantly higher at 75% RDF and 100% RDF than at 50% RDF. However, there was no significant difference in nutrients uptake between 75% RDF and 100% RDF, which suggests saving of fertilizer to the tune of 25%. Fertigation treatments recorded significantly higher nutrients uptake as compared to conventional soil application of normal fertilizers with drip irrigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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