

Original Research Article

NPK uptake of tomato as influenced by irrigation regimes and fertigation levels under greenhouse condition

ABSTRACT

A field experiment was conducted for 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 tomato hybrid STH-801 under greenhouse. The experiment was laid out with three drip irrigation regimes (40, 60 and 80 % ETc) and three fertigation levels (50, 75 and 100% RDF) in RCBD design with factorial concept and replicated thrice with one absolute control. The results showed that NPK uptake by plant 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 per cent ETc showed significant reduction on NPK uptake by plant as compared to I₂ (60% ETc) and I₃ (80% ETc) irrigation regimes. However, non-significant difference was recorded in nutrient uptake between I₂ (60% ETc) and I₃ (80% ETc). The effect of fertigation levels on nutrient uptake was also significant at fruiting and harvesting stage. The uptake NPK by plant was significantly higher at F₂ (75% RDF) and F₃ (100% RDF) than at F₁ (50% RDF). However, there was no significant difference in nutrient uptake between F₂ (75% RDF) and F₃ (100% RDF), which suggests saving of fertilizer to the tune of 25 per cent. Fertigation treatments recorded significantly higher nutrient uptake as compared to conventional soil application of normal fertilizers with drip irrigation.

Key words: 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

31 conditions and also incidence of pests and diseases. Tomato (*Solanum lycopersicum* L.) is the
32 second most important vegetable crop next to potato throughout the world and grown in a
33 wide range of climatic conditions.

34 Fertilization and irrigation are important management practices to improve crop
35 productivity. Compared with cereal production, vegetable cultivation often requires more
36 intensive management and larger amounts of fertilizers and irrigation water [1]. The
37 overgrowing population and recent droughts are putting water resources under pressure and
38 calling for new approaches for water planning and management. Irrigation is the major
39 consumer of diverted water from surface and groundwater in the world. Therefore, it must be
40 carried with high efficiency. One pre-requisite for efficient irrigation is knowledge of
41 consumptive use of major crops or their evapotranspiration. Such information is required to
42 minimize percolation losses, runoff and thus environmental pollution [2]. Studies carried out
43 across different countries including India have confirmed that irrigation plays a paramount
44 role in increasing the yield and enhancing cropping intensity as well as productivity of crops
45 [3]. A correct determination of irrigation scheduling is one of the main factors in achieving
46 high yields and avoiding loss of quality in greenhouse tomato [4].

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

55 Under drip irrigation only a small portion of soil volume around each plant is wetted,
56 so crop root growth is essentially restricted to this wetted volume of soil and nutrients within
57 that volume are subject to accelerated crop uptake. The better performance under drip was
58 attributed to maintenance of favorable soil water conditions in the root zone, which in turn
59 helped the plants to utilize water and nutrients more efficiently from the wetted area [8]. In a
60 fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily
61 controlled. The availability of nutrients evenly with frequent fertigation was the responsible
62 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. The fertilizers are becoming costly input day by day. A higher efficiency is possible with the help of pressurized irrigation system is placed around the plant roots uniformly and allow for rapid uptake of nutrient by plant [9].

2. Material and methods

2.1. Site characteristics

Field experiments were conducted for 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 at $15^{\circ}26'$ N latitude and $75^{\circ}07'$ E longitude at an altitude of 678 m above mean sea level. The soil of experimental plot belongs to textural class sandy loam 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 FYM per ha as per package of practices.

2.2. Experimental treatments and design

Three drip irrigation regimes ($I_1 = 40\%$, $I_2 = 60\%$ and $I_3 = 80\%$ of ET_c) 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 (RCBD) with 9 treatment combinations and replicated three times with one absolute control (drip irrigation at 100 % ET_c and soil application of 100% RDF in the form of conventional fertilizer).

During initial growth stage, all the experimental plots received equal amount of irrigation water (100% ET_c) to ensure well establishment of tomato plants, afterwards, water 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) was applied in the form of water soluble

fertilizer in equal doses for 16 times (15 DAP to 120 DAP). Whereas in control treatment 50, 100 and 100% of N, P₂O₅ and K₂O of recommended dose in the form of conventional fertilizers along with 38 tons FYM per ha was 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 length, 20 m width with central height of 6 m. Drip irrigation system was installed for the complete cropped area. Land area inside the polyhouse 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 height and 100 cm width 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. Inline dripper lateral had an emitting point for every 3 m interval with a discharge of 2 lit/hour. Raised row system of planting with zigzag manner was followed to have more aeration between the plants. A distance of 50 cm between the rows and 60 cm between plants in the row was followed for planting. Raised bed of 30 cm height and 1 m wide was prepared with 50 cm gap between beds. Tomato seedlings transplanted at 22 day old in the polyhouse 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 season, 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 NPK nutrients were determined using standard procedure.

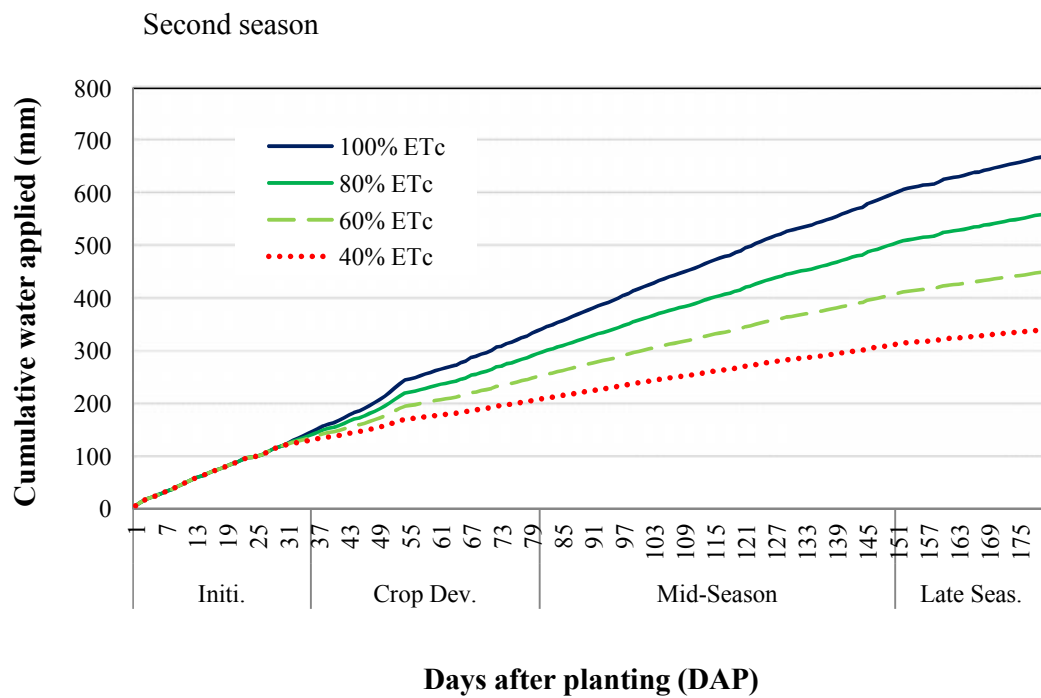
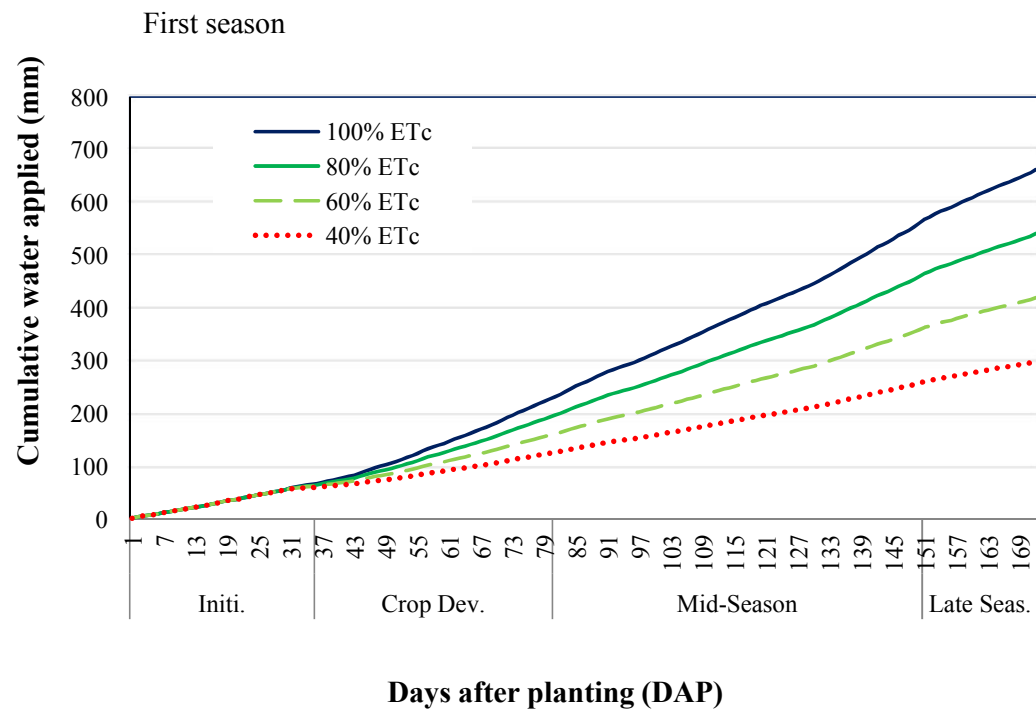


Fig 1. Cumulative water applied (mm) to tomato for different irrigation regimes during the two seasons

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 with control.

However, at fruiting stage, I_3 (80% ETc) recorded the highest N uptake (100.35 and 88.21 kg N ha⁻¹ in first and second season, respectively) followed by I_2 (60% ETc) (89.78 and 85.87 kg N ha⁻¹ in first and second season, respectively). However, they were on par and significantly superior over I_1 (40% ETc) which recorded the lowest N uptake (77.82 and 66.30 kg N ha⁻¹ in first and second season, respectively). Similarly, at harvesting stage, the irrigation regimes showed significant effect on N uptake by plant. The maximum N uptake (137.64 and 124.84 kg N ha⁻¹ in first and second season, respectively) was recorded with I_2 (60% ETc) which was on par with I_3 (80% ETc) (136.62 and 124.43 kg N ha⁻¹ in first and second season, respectively). However, irrigation at I_1 (40% ETc) recorded significantly lower N uptake (117.26 and 104.16 kg N ha⁻¹ in first and second season, respectively) as compared with I_2 (60% ETc) and I_3 (80% ETc) irrigation regimes.

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

Likewise, interaction effect between irrigation regimes and fertigation levels was also significant with respect to N uptake at fruiting and harvesting stage. The treatment

combination I_2F_2 , I_2F_3 , I_3F_2 and I_3F_3 recorded higher N uptake, which were on par and significantly superior over the rest of fertigation treatments and control.

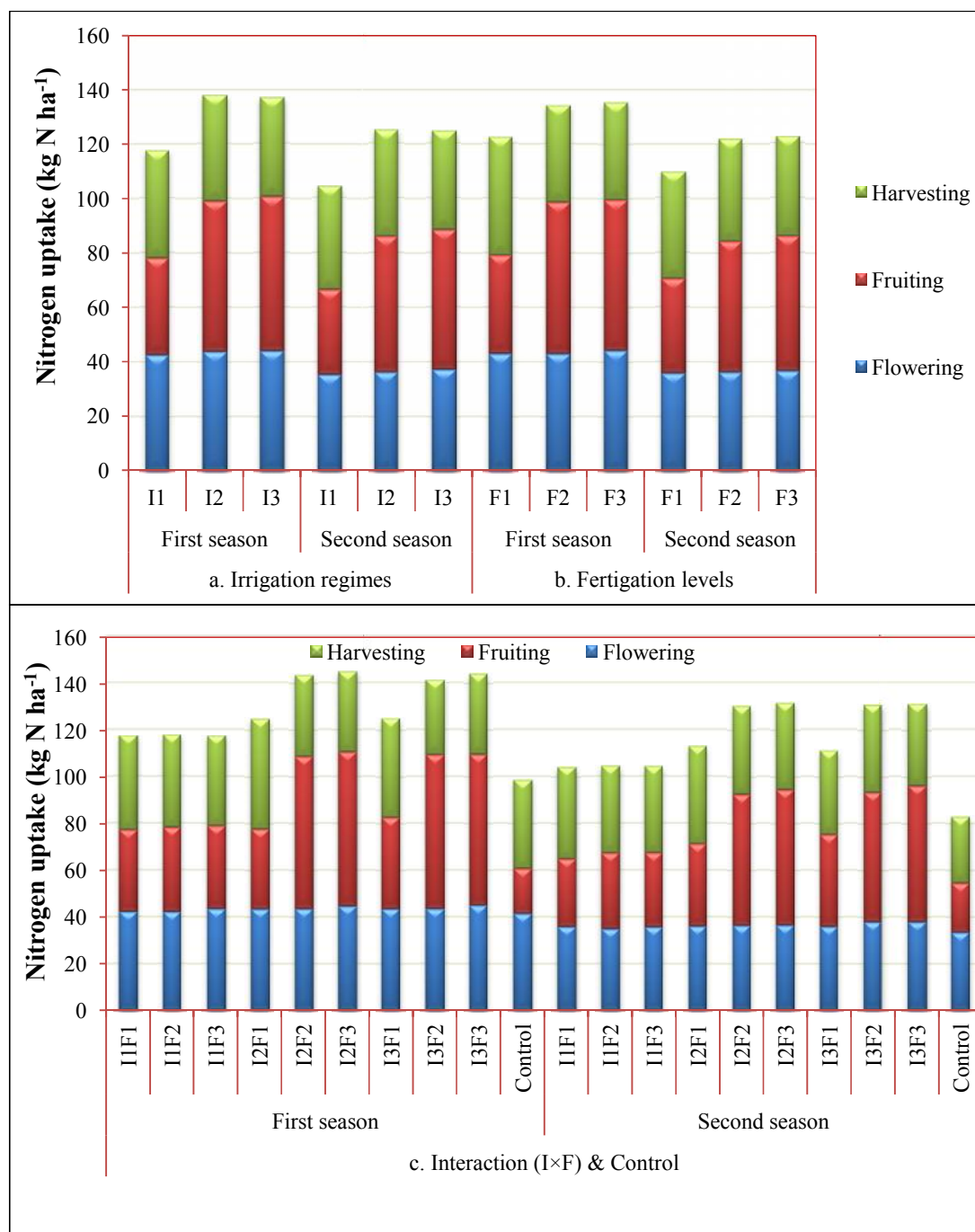


Fig 2. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on nitrogen uptake (kg N ha⁻¹) at different growth stages of tomato in both seasons



162 3.2 Phosphorus uptake

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

166 At fruiting stage, P uptake was significantly influenced by irrigation regimes.
167 Application of I_3 (80% ETc) recorded the highest P uptake (12.84 and 11.07 kg P ha⁻¹ in first
168 and second season, respectively) at fruiting stage which was on par with I_2 (60% ETc) (12.66
169 and 10.79 kg P ha⁻¹ in first and second season, respectively). However, irrigation at I_1 (40%
170 ETc) recorded significantly lower P uptake (9.47 and 7.49 kg P ha⁻¹ in first and second
171 season, respectively) at fruiting stage as compared to rest of irrigation regimes. Similarly, at
172 harvesting stage, the effect of irrigation regimes on P uptake was also significant. Irrigation at
173 I_2 (60% ETc) recorded the highest P uptake (23.42 and 20.32 kg P ha⁻¹ in first and second
174 season, respectively) which was on par with I_3 (80% ETc) (23.31 and 20.15 kg P ha⁻¹ in first
175 and second season, respectively). However, I_1 (40% ETc) recorded significantly lower P
176 uptake (19.68 and 16.85 kg P ha⁻¹ in first and second season, respectively) as compared with
177 other irrigation regimes.

178 The fertigation levels showed also significant influenced on P uptake at fruiting and
179 harvesting stage. At fruiting stage, F_3 (100% RDF) registered the highest P uptake (12.74 and
180 10.82 kg P ha⁻¹ in first and second season, respectively) which was on par with F_2 (75%
181 RDF) (12.62 and 10.60 kg P ha⁻¹ in first and second season, respectively). However,
182 significantly the lowest P uptake (9.61 and 7.94 kg P ha⁻¹ in first and second season,
183 respectively) was registered with fertigation at F_1 (50% RDF). Likewise, at harvesting stage,
184 fertigation at F_3 (100% RDF) recorded the highest P uptake (23.57 and 20.08 kg P ha⁻¹ in first
185 and second season, respectively) which was on par with F_2 (75% RDF) (23.25 and 19.76 kg P
186 ha⁻¹ in first and second season, respectively). However, significantly the lowest P uptake
187 (19.59 and 17.49 kg P ha⁻¹ in first and second season, respectively) was recorded by F_1 (50%
188 RDF).

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

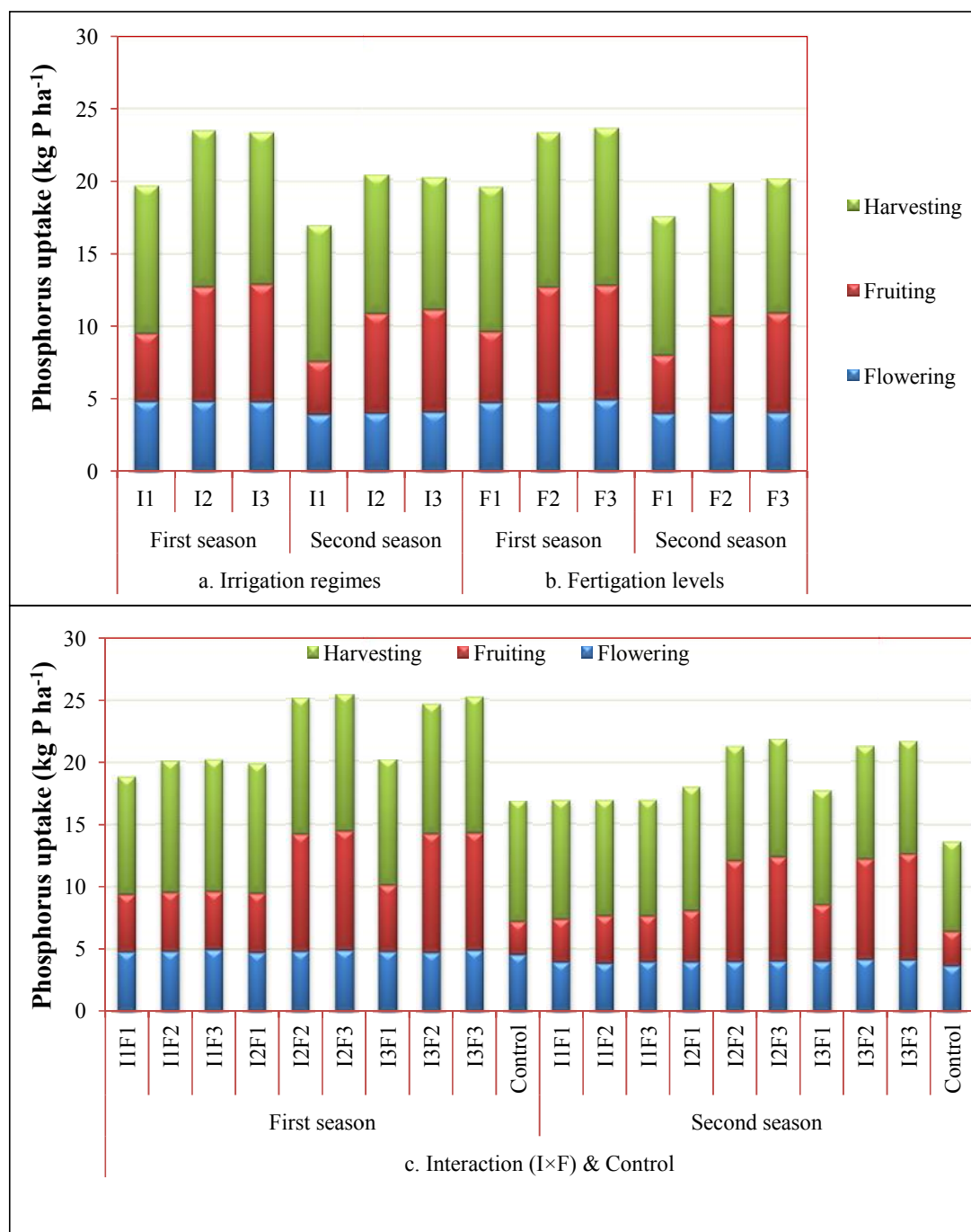


Fig 3. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on phosphorus uptake (kg P ha⁻¹) at different growth stages of tomato in both seasons

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 control.

However, at fruiting stage, K uptake was significantly influence due to irrigation regimes, comparatively higher K uptake (128.21 and 112.24 kg K ha⁻¹ in first and second season, respectively) was noticed in I₃ (80% ETc), this was followed by I₂ (60% ETc) (126.90 and 109.79 kg K ha⁻¹ in first and second season, respectively) which were on par and significantly superior over I₁ (40% ETc) (96.64 and 80.62 kg K/ha in first and second season, respectively). Similarly, the K uptake differed significantly due to irrigation regimes at harvesting stage. The irrigation regime I₂ (60% of ETc) has registered highest K uptake (176.89 and 157.38 kg K ha⁻¹ in first and second season, respectively), which was on par with I₃ (80% ETc) (173.82 and 155.61 kg K ha⁻¹ in first and second season, respectively). However, irrigation at I₁ (40% ETc) recorded significantly lower K uptake (143.86 and 122.82 kg K ha⁻¹ in first and second season, respectively) as compared to other irrigation regimes.

Data also showed that, there was significant increase in K uptake with the increase in the levels of fertigation dose at fruiting and harvesting stage. F₃ (100% RDF) showed highest K uptake (127.36 and 108.93 kg K ha⁻¹ in first and second season, respectively) at fruiting stage and this was followed by F₂ (75% RDF) (126.60 and 107.99 kg K ha⁻¹ in first and second season, respectively) which were on par and significantly superior over F₁ (50%RDF) (97.79 and 85.72 kg K ha⁻¹ in first and second season, respectively). Likewise, at harvesting stage, the highest K uptake of 173.30 and 155.18 kg K ha⁻¹ in first and second season, respectively, was recorded by F₃ (100% RDF) and was followed by F₂ (75% RDF) with 171.38 and 152.07 kg K ha⁻¹ in first and second season, respectively. However, significantly the lowest K uptake was noticed in F₁ (50%RDF) with 149.88 and 128.56 kg K ha⁻¹ in first and second season, respectively.

The interaction effect between irrigation regimes and fertigation levels were significantly different for K uptake at fruiting and harvesting stage. Significantly higher K uptake was noticed in the treatment combination of I₂F₂, I₂F₃, I₃F₂ and I₃F₃ which were on par and significantly superior over other fertigation treatments and control.

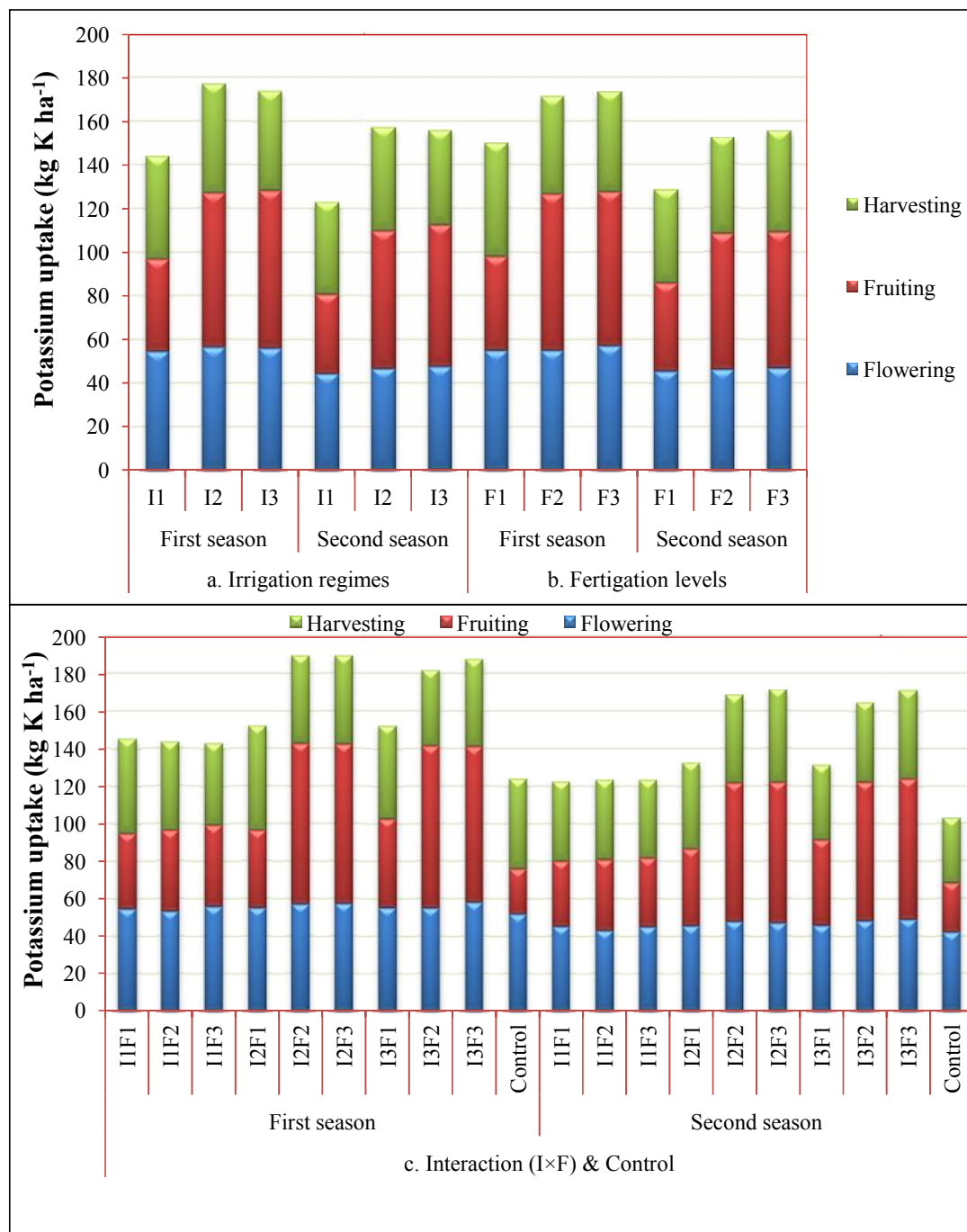


Fig 4. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on potassium uptake (kg K ha⁻¹) at different growth stages of tomato in both seasons

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. Uptake of NPK by plant was significantly influenced 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. This might be due to the fact that during initial growth stage (35 DAP), all experimental plots received equal amount of irrigation water (100% ETc) ensure well establishment of tomato plants, afterwards, water applied according to irrigation regimes. In addition, young tomato plants need lower amounts of nutrients because their absolute growth rates (dry matter produced per unit time) are low [10].

At fruiting and harvesting stage, the irrigation regimes showed significant retraction on NPK uptake by plant under water stress treatments (40% ETc) as compared to I₂ (60% ETc) and I₃ (80% ETc) irrigation regimes. However, non-significant difference was recorded in nutrient uptake between I₂ (60% ETc) and I₃ (80% ETc). Total nutrient uptake followed the pattern of biomass accumulation. So, the lower growth and dry matter production in I₁ (40% ETc) might have contributed to lower nutrients uptake by plant. Also, it is likely that decreased soil water availability reduced nutrient uptake due to decrease in mobility as a result of increased impedance [11].

The effect of fertigation levels on nutrient uptake revealed that as the rate of NPK application increased, the nutrient uptake also increased. The uptake of NPK by plant was significantly higher at F₂ (75% RDF) and F₃ (100% RDF) than at F₁ (50% RDF). However, there was no significant difference in nutrient uptake between F₂ (75% RDF) and F₃ (100% RDF), which indicates a saving of nitrogen to the tune of 25 per cent. This might be due to the better availability of nutrients in 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 because of leaching.

In addition, fertigation treatments recorded significantly higher nutrient uptake as compared to soil application of conventional fertilizers with drip irrigation. This is the evidence for the longer activity in fertigation where nutrients were applied through 16 split doses to match the nutrients uptake by the crop. The applied NPK soluble form in fertigation treatments may have been distributed better throughout root zone of tomato than control (soil application of conventional fertilizers) and making more available nutrients for plant uptake. The normal fertilizer however, generally tends to cause uneven distribution of fertilizers in the root zone [10].

5. CONCLUSION

Uptake of NPK by plant was significantly enhanced by irrigation regime, 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 per cent ETc showed significant reduction on NPK uptake by plant as compared to I₂ (60% ETc) and I₃ (80% ETc) irrigation regimes. However, non-significant difference was recorded in nutrient uptake between I₂ (60% ETc) and I₃ (80% ETc). The effect of fertigation levels on nutrient uptake was also significant at fruiting and harvesting stage. The uptake NPK by plant was significantly higher at F₂ (75% RDF) and F₃ (100% RDF) than at F₁ (50% RDF). However, there was no significant difference in nutrient uptake between F₂ (75% RDF) and F₃ (100% RDF), which suggests saving of fertilizer to the tune of 25 per cent. Fertigation treatments recorded significantly higher nutrient uptake as compared to conventional soil application of normal fertilizers with drip irrigation.

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