

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

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 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 per cent ETC showed significant reduction in NPK uptake by plants as compared to I_2 (60% ETC) and I_3 (80% ETC) irrigation regimes. However, non-significant difference was recorded in nutrients uptake between I_2 (60% ETC) and I_3 (80% ETC). 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 (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 (75% RDF) and F_3 (100% RDF). Fertigation treatments recorded significantly higher nutrients 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

31 for working efficiency as well as for better crop growth. Greenhouses protect the crop from
32 varied climatic conditions like wind, rainfall, excess solar radiation, extreme temperature
33 conditions and also incidence of pests and diseases. Tomato (*Solanum lycopersicum*L.) is the
34 second most important vegetable crop next to potato throughout the world and grown in a
35 wide range of climatic conditions.

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

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

57 Under drip irrigation only a small portion of soil volume around each plant is wetted,
58 so crop root growth is essentially restricted to this wetted volume of soil and nutrients within
59 that volume are subject to accelerated crop uptake. The better performance under drip **has**
60 **been** attributed to maintenance of favorable soil water conditions in the root zone, which in
61 turn helped the plants to utilize water and nutrients more efficiently from the wetted area [8].
62 In a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are

63 easily controlled. The availability of nutrients evenly with frequent fertigation was
64 responsible for the improvement of nutrient uptake and recovery in the root zone coupled
65 with reduced loss of nutrients primarily because of less leaching under higher fertigation
66 rates[9].

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

70 2. Material and methods

71 2.1. Site characteristics

72 Field experiments were conducted in two seasons during 2012-2013 in a natural
73 ventilated polyhouse at Hi-Tech-Horticulture unit, Agricultural Research Station, Saidapur,
74 UAS, Dharwad, Karnataka, India. Dharwad is geographically located onlatitude15°-26' N and
75 longitude75°-7' E at an altitude of 678 m above mean sea level. The soil of the experimental
76 plot is of sandy loamtexturewith a pH of 7.3 and EC of 1.75 dSm⁻¹, low in available nitrogen
77 (240 kg ha⁻¹), medium in available phosphorus (24 kg ha⁻¹) and high in available potassium
78 (311 kg ha⁻¹). The recommended dose of fertilizers (RDF) for tomato hybrid STH-801 is
79 250:250:250 kg N, P₂O₅ and K₂O per ha and 38 tonnesfarmyard manure(FYM) per ha as per
80 cultivation practices.

81 2.2. Experimental treatments and design

82 Three drip irrigation regimes (I₁= 40%, I₂= 60% and I₃= 80% of ET_c) were based on
83 accumulated pan evaporation (E_{pan}) and three fertigation levels (F₁= 50%, F₂= 75% and F₃=
84 100% of RDF) in the form of water soluble fertilizer were laid out in factorial randomized
85 complete block designwith 9 treatment combinations and replicated three times with one
86 absolute control (drip irrigation at 100% ET_c and soil application of 100% RDF in the form
87 of conventional fertilizer).

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

93 For fertigation treatments 20% RDF (conventional fertilizers) + 38 tons of FYM per
94 ha was applied as basal dose. The remaining RDF for F₁ fertigation level 30 % (75:75:75 N,
95 P₂O₅ and K₂O kg per ha), F₂ 55% (137.5:137.5:137.5 N, P₂O₅ and K₂O kg per ha) and F₃
96 80% (200:200:200 N, P₂O₅ and K₂O kg per ha) were applied in the form of water soluble
97 fertilizer in equal doses for 16 times (15 DAP to 120 DAP). However, in the control
98 treatment 50, 100 and 100% of N, P₂O₅ and K₂O of recommended dose in the form of
99 conventional fertilizers along with 38 tons FYM per ha were applied as basal dose. The
100 remaining 50% of N was applied in 2 splits (30 and 60 DAP).

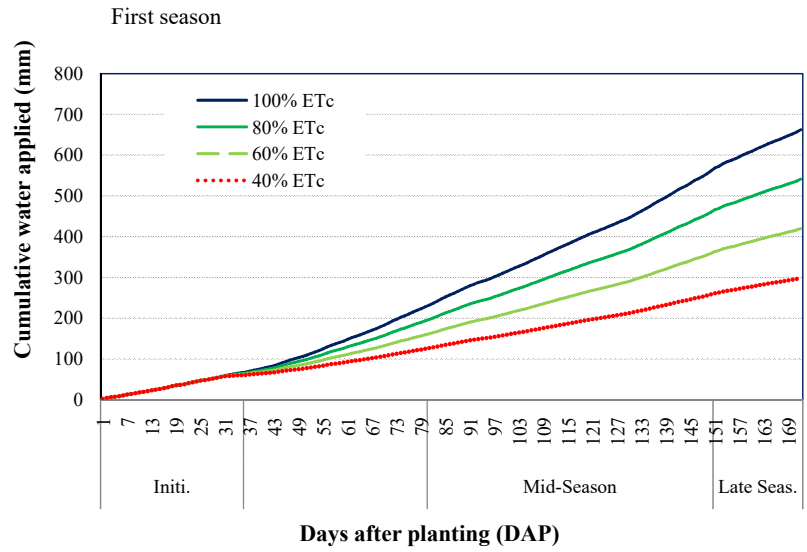
101 2.3. Experimental procedure

102 The experiment was carried out in a naturally ventilated polyhouse(NVP) with a size
103 of 28 m long, 20 m wide with central height of 6 m. Drip irrigation system was installed for
104 the complete cropped area. Land area inside the polyhouse was thoroughly dug to a depth of
105 30 cm. The land was incorporated with farmyard manure, urea, diammonium phosphate,
106 muriate of potash also applied as basal dose. Raised beds of 30 cm high and 100 cm wide to a
107 length of 25 m were prepared with the walking space between beds. At the centre of the bed,
108 two inline dripper laterals were placed. The inline dripper lateral had an emitting point for
109 every 30 cm interval with a discharge of 2 lit/hour. Paired row system of planting in a zigzag
110 pattern was employed to ensure improved aeration among the plants. A distance of 50 cm
111 between the rows and 60 cm between plants in the row was employed as the planting
112 distance. Raised beds of 30 cm high and 1 m wide was prepared with 50 cm gap between
113 beds. Tomato seedlings were transplanted at 22 day old on 29th September 2012 and 7th April
114 2013 for first and second season, respectively. Fruits were harvested at colour breaking stage.
115 Harvesting of tomato fruits started at 90 days after transplanting and continued till 172 and
116 180 days after transplanting for first and second seasons, respectively.

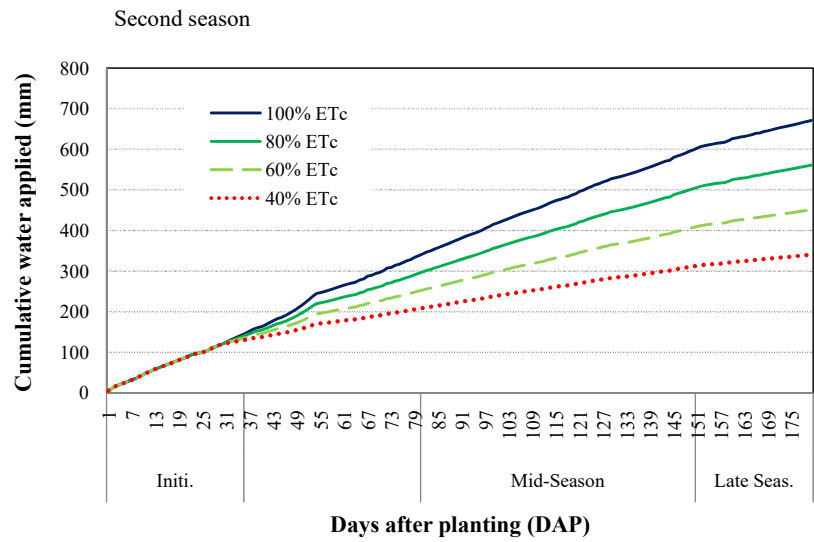
117 Whole plant samples were collected from all the plots at critical stages of crop
118 growth for chemical analysis. These samples were oven dried at 70 ° C till constant weight
119 was recorded. The samples were ground in a Willey mill and preserved in butter paper
120 bags. The uptake of nitrogen,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

123

124



125



126

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

129

130

131 3. Results

132 3.1 Nitrogen uptake

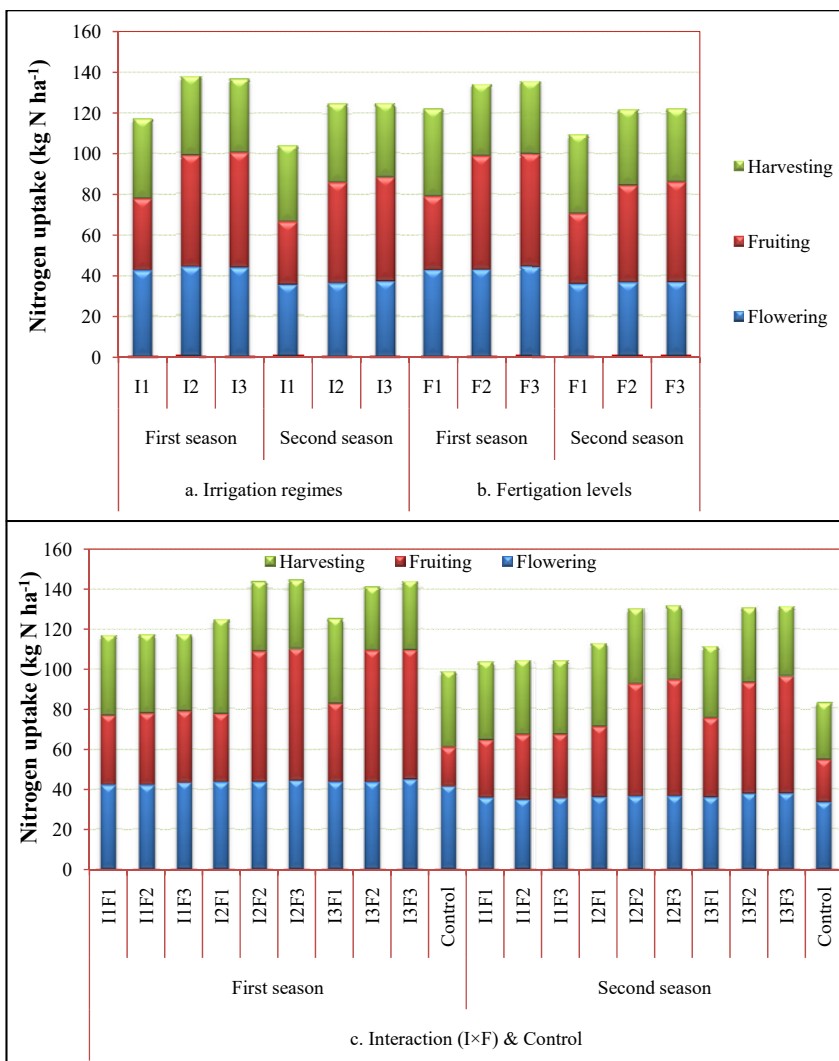
133 At flowering stage, the effect of irrigation regimes, fertigation levels and their
134 interaction was not significant on N uptake (Fig 2). Similarly, all fertigation treatments did
135 not significantly influence N uptake at flowering stage as compared to the control.

136 However, at fruiting stage, I_3 (80% ETc) recorded the highest N uptake (100.35 and
137 88.21 kg N ha⁻¹ in the first and second seasons, respectively) followed by I_2 (60% ETc) (98.78
138 and 85.87 kg N ha⁻¹ in the first and second seasons, respectively). However, they were at par
139 and significantly superior to I_1 (40% ETc) which recorded the lowest N uptake (77.82 and
140 66.30 kg N ha⁻¹ in the first and second seasons, respectively). Similarly, at harvesting stage,
141 the irrigation regimes showed significant effect on N uptake by the plants. The maximum N
142 uptake (137.64 and 124.84 kg N ha⁻¹ in the first and second seasons, respectively) was
143 recorded with I_2 (60% ETc) which was at par with I_3 (80% ETc) (136.62 and 124.43 kg N ha⁻¹
144 in the first and second seasons, respectively). However, irrigation at I_1 (40% ETc) recorded
145 significantly lower N uptake (117.26 and 104.16 kg N ha⁻¹ in the first and second seasons,
146 respectively) as compared to I_2 (60% ETc) and I_3 (80% ETc) irrigation regimes.

147 Irrespective of irrigation regimes, the effect of fertigation levels on N uptake was also
148 significant at fruiting and harvesting stages. Fertigation at 100% RDF (F_3) recorded the
149 highest N uptake (99.46 and 85.89 kg N ha⁻¹ in the first and second seasons, respectively) at
150 fruiting stage which was at par with F_2 (75% RDF) (98.52 and 84.24 kg N ha⁻¹ in the first and
151 second seasons, respectively). However, fertigation at F_1 (50% RDF) registered significantly
152 lower N uptake (78.96 and 70.26 kg N ha⁻¹ in the first and second seasons, respectively) at
153 fruiting stage as compared to other fertigation regimes. The N uptake also decreased
154 significantly under low fertigation level treatments (50% RDF) at harvesting stage.
155 Application of 100% RDF through fertigation (F_3) recorded the highest N uptake (135.28 and
156 122.32 kg N ha⁻¹ in the first and second seasons, respectively) at harvesting stage which was
157 at par with F_2 (75% RDF) (133.99 and 121.80 kg N ha⁻¹ in the first and second seasons,
158 respectively) and significantly lowest N uptake (122.25 and 109.30 kg N ha⁻¹ in the first and
159 second seasons, respectively) was recorded with F_1 (50% RDF).

160 Likewise, interaction effect between irrigation regimes and fertigation levels was also
 161 significant with respect to N uptake at fruiting and harvesting stages. The treatment
 162 combinations I₂F₂, I₂F₃, I₃F₂ and I₃F₃ recorded higher N uptake, which were at par and
 163 significantly superior to the rest of the fertigation treatments and control.

164



166

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

3.2 Phosphorus uptake

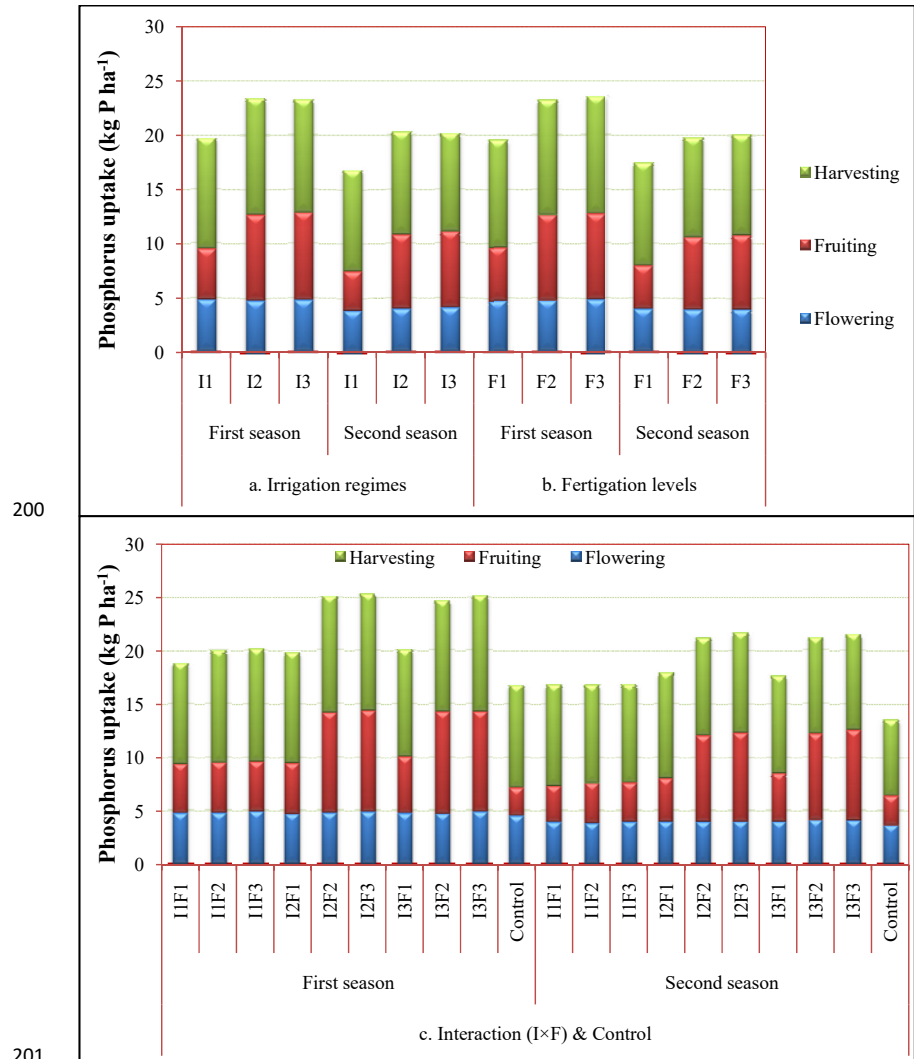
At flowering stage, irrigation regimes, fertigation levels and interaction did not influence significantly on P uptake (Fig 3). Similarly, fertigation treatments did not differ significantly with respect to P uptake at flowering stage as compared to the control.

At fruiting stage, P uptake was significantly influenced by irrigation regimes. Application of 80% ETc(I₃) 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 I₂ (60% ETc) (12.66 and 10.79 kg P ha^{-1} in the first and second seasons, respectively). However, irrigation at 40% ETc(I₁) 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 60% ETc(I₂) 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 I₃ (80% ETc) (23.31 and 20.15 kg P ha^{-1} in the first and second seasons, respectively). However, I₁ (40% ETc) 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, F₃ (100% RDF) 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 F₂ (75% RDF) (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 F₁ (50% RDF). Likewise, at harvesting stage, fertigation at F₃ (100% RDF) 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 F₂ (75% RDF) (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 F₁ (50% RDF).

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

198 recorded with the treatment combination of I_2F_2 , I_2F_3 , I_3F_2 and I_3F_3 , which were atpar and
 199 significantly superior over the rest of the fertigation treatments and control.



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

204 3.3 Potassium uptake

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

208 However, at fruiting stage, K uptake was significantly influenced due to irrigation
209 regimes, comparatively higher K uptake (128.21 and 112.24 kg K ha⁻¹ in the first and second
210 seasons, respectively) was noticed in I₃ (80% ETc), this was followed by I₂ (60%
211 ETc) (126.90 and 109.79 kg K ha⁻¹ in the first and second seasons, respectively) which were
212 at par and significantly superior to I₁ (40% ETc) (96.64 and 80.62 kg K/ha in the first and
213 second seasons, respectively). Similarly, the K uptake differed significantly due to irrigation
214 regimes at harvesting stage. The irrigation regime I₂ (60% of ETc) has registered highest K
215 uptake (176.89 and 157.38 kg K ha⁻¹ in the first and second seasons, respectively), which was
216 at par with I₃ (80% ETc) (173.82 and 155.61 kg K ha⁻¹ in the first and second seasons,
217 respectively). However, irrigation at I₁ (40% ETc) recorded significantly lower K uptake
218 (143.86 and 122.82 kg K ha⁻¹ in the first and second seasons, respectively) as compared to
219 the other irrigation regimes.

220 Data also showed that, there was significant increase in K uptake with the increase in
221 the levels of fertigation dose at fruiting and harvesting stages. F₃ (100% RDF) showed
222 highest K uptake (127.36 and 108.93 kg K ha⁻¹ in the first and second seasons, respectively)
223 at fruiting stage and this was followed by F₂ (75% RDF) (126.60 and 107.99 kg K ha⁻¹ in the
224 first and second seasons, respectively) which were at par and significantly superior to F₁
225 (50% RDF) (97.79 and 85.72 kg K ha⁻¹ in the first and second seasons, respectively).
226 Likewise, at harvesting stage, the highest K uptake of 173.30 and 155.18 kg K ha⁻¹ in the first
227 and second seasons, respectively, was recorded by F₃ (100% RDF) and was followed by F₂
228 (75% RDF) with 171.38 and 152.07 kg K ha⁻¹ in the first and second seasons, respectively.
229 However, significantly the lowest K uptake was noticed in F₁ (50% RDF) with 149.88 and
230 128.56 kg K ha⁻¹ in the first and second seasons, respectively.

231 The interaction effect between irrigation regimes and fertigation levels were
232 significantly different for K uptake at fruiting and harvesting stages. Significantly higher K
233 uptake was noticed in the treatment combination of I₂F₂, I₂F₃, I₃F₂ and I₃F₃ which were at par
234 and significantly superior to the rest of the fertigation treatments and control.

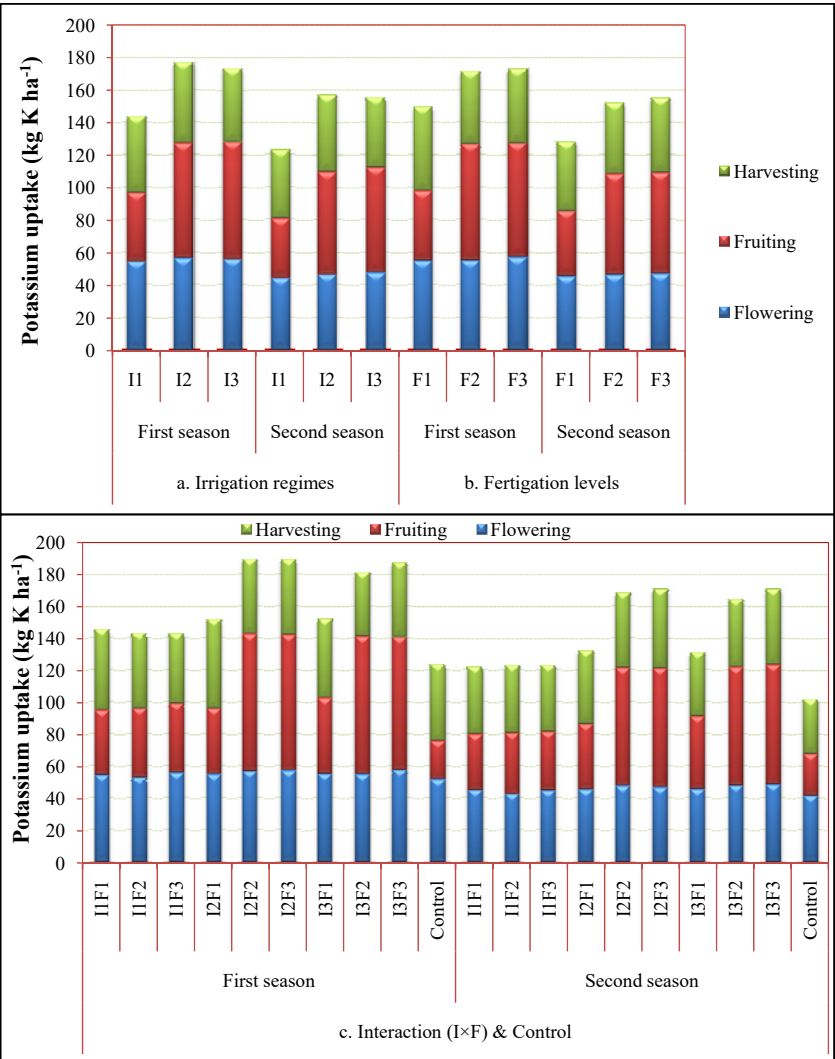


Fig 4. Effect of irrigation regimes, fertigation levels and interaction (I×F) & control on potassium uptake (kg K ha⁻¹) at different growth stages of tomato in both seasons

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 as evidenced by Li *et al.* [10]. The uptake of NPK by plants was significantly influenced by irrigation regimes,

243 fertigation levels and their interaction at fruiting and harvesting stages. However,
244 no significant difference was recorded in nutrients uptake at flowering stage. This might be
245 due to the fact that during the initial growth stage (35 DAP), all the experimental plots
246 received equal amount of irrigation water (100% ETc) to ensure proper establishment of
247 tomato plants, thereafter, water was applied according to the specified irrigation regimes,
248 herein referred to as the irrigation treatments.

249 At fruiting and harvesting stage, the irrigation regimes showed significant retraction
250 on NPK uptake by plant under water stressed treatment (40% ETc) as compared to I₂ (60%
251 ETc) and I₃ (80% ETc) irrigation regimes. However, no significant difference was recorded in
252 nutrients uptake between I₂ (60% ETc) and I₃ (80% ETc). The lower growth and dry matter
253 production in I₁ (40% ETc) might have contributed to lower nutrients uptake by plant. Also,
254 it is likely that decreased soil water availability reduced nutrients uptake due to decrease in
255 nutrients mobility [11].

256 The effect of fertigation levels on nutrients uptake revealed that as the rate of NPK
257 application increased, the nutrients uptake also increased. The uptake of NPK by the plants
258 was significantly higher at F₂ (75% RDF) and F₃ (100% RDF) than at F₁ (50% RDF).
259 However, there was no significant difference in nutrients uptake between F₂ (75% RDF) and
260 F₃ (100% RDF), which indicates a saving of nitrogen to the tune of 25 per cent. This might
261 due to the better availability of nutrients in the crop root zone as a result of frequent
262 application of nutrients coupled with better root activity. Further, it was also due to the
263 reduced loss of nutrients primarily from leaching.

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

273

274 5. CONCLUSION

275 Uptake of NPK by tomato was significantly enhanced by irrigation regimes,
276 fertigation levels and their interaction at fruiting and harvesting stages. However,
277 no significant difference was recorded in nutrients uptake at flowering stage. Irrigation regime
278 at 40 per cent ETc resulted in significant reduction in NPK uptake as compared to I₂ (60%
279 ETc) and I₃ (80% ETc) irrigation regimes. However, no significant difference was recorded in
280 nutrients uptake between I₂ (60% ETc) and I₃ (80% ETc). The effect of fertigation levels on
281 nutrients uptake was also significant at fruiting and harvesting stages. The uptake of NPK by
282 plant was significantly higher at F₂ (75% RDF) and F₃ (100% RDF) than at F₁ (50% RDF).
283 However, there was no significant difference in nutrients uptake between F₂ (75% RDF) and
284 F₃ (100% RDF), which suggests saving of fertilizer to the tune of 25 per cent. Fertigation
285 treatments recorded significantly higher nutrients uptake as compared to conventional soil
286 application of normal fertilizers with drip irrigation.

287 References

- 288 1. Thompson RB, Martinez-Gaitan C, Gallardo M, Gimenez C, Fernandez MD.
289 Identification of irrigation and N management practices that contribute to nitrate leaching
290 loss from an intensive vegetable production system by use of a comprehensive survey.
291 Agric. Water Manage. 2007; 89: 261-274.
- 292 2. Orgaz F, Fernandez MD, Bonachela S, Gallardo M, Fereres E. Evapotranspiration of
293 horticultural crops in an unheated plastic greenhouse. Agric. Water Manage. 2005; 72: 81-
294 96.
- 295 3. Dhawan BD. Role of irrigation in raising intensity of cropping. J. Indian Scho. Poli.
296 Eco. 1988; 3(4): 632-671.
- 297 4. Yuan B, Kang Y, Nishiyama S. Drip irrigation scheduling for tomatoes in unheated
298 greenhouses. Irrig. Sci. 2001; 20: 149-154.
- 299 5. Shen WS, Lin XG, Shi WM, Min J, Gao N, Zhang HY, Yin R, He X H. Higher rates of
300 nitrogen fertilization decrease soil enzyme activities, microbial functional diversity and
301 nitrification capacity in a Chinese polytunnel greenhouse vegetable land. Pl. Soil. 2010;
302 337(1-2): 137-150.
- 303 6. Shrestha RK, Cooperband LR, MacGuidwin AE. Strategies to reduce nitrate leaching into
304 groundwater in potato grown in sandy soils: case study from North Central USA.
305 American J. Pot. Res. 2010; 87: 229-244.

- 306 7. Harmanto, Salokhe VM, Babel MS, Tantau HJ. Water requirement of drip irrigated
307 tomatoes grown in greenhouse in tropical environment. Agric.Water Manage.2005;71(3):
308 225-242.
- 309 8. Singh AK, Chakraborty D, Mishra B, Singh DK. Nitrogen and potassium dynamics in
310 fertigation system. 17th world congress of soil science, Thailand. 2002;1045: 1-10.
- 311 9. Kumar P, Sahu RL. Effect of irrigation and fertigation levels on cabbage (*Brassica*
312 *oleracea* var. Capitata L.). Progres. Horti.2013;45(2): 366-372.
- 313 10. Li H, Cong R, Ren T, Li X, Ma C, Zheng L, Zhang Z, Lu J. Yield response to N fertilizer
314 and optimum N rate of winter oilseed rape under different soil indigenous N supplies.
315 Field Crops Res. 2015; 181: 52-59.
- 316 11. Seiffert S, Kaselowsky J, Jungk A, Classen N. Observed and calculated potassium uptake
317 by maize as affected by soil water content and bulk density. Agron. J.1995; 87: 1070-
318 1077.
- 319 12. Shedeed SI, Zaghoul SM, Yassen AA, Effect of method and rate of fertilizer application
320 under drip application on yield and nutrient uptake by tomato. Ozean J. Appl. Sci.2009; 2:
321 139-147.