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Effect of phyto-chemicals with nutrients on physiological traits, yield and quality of tomato (*Solanum lycopersicum*)

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Abstract
An experiment was conducted at field condition during 2018 as summer irrigated crop to study the effect of phyto-chemicals (naphthalene acetic acid-NAA-20 ppm, chloro choline chloride-CCC- 200 ppm, gibberellic acid-GA_3-20 ppm and salicylic acid-SA-100 ppm) with nutrients nitrogen (2% urea) and phosphorus (2% mono ammonium phosphate-MAP) alone and combinations on physiological parameters and yield of tomato by foliar spray at 30 and 60 days after transplanting. The physiological parameters like chlorophyll, soluble protein content, number of flower per plant, total sugars, ascorbic acid and yield were estimated. Foliar spray of 2% urea with 100 ppm salicylic acid acid registered higher chlorophyll content (2.36 mg g^{-1}), soluble protein (12.9 mg g^{-1}), yield (32.42 t ha^{-1}), total sugars (36.3 g 100 g^{-1}) and ascorbic acid (27 g 100 g^{-1}). However, the highest number of flowers (46) was recorded by foliar spray of 2% urea + 20 ppm GA_3 followed by 2% MAP with 100 ppm salicylic acid (44).

Keywords: tomato, urea, MAP, NAA, GA_3, CCC, salicylic acid, chlorophyll, soluble protein

Introduction

Tomato (*Solanum lycopersicum*) is an important vegetable crop with good source of vitamins A, B and C. The popularity of tomato is rising among consumers because of its high level of anti-oxidants like lycopene and beta-carotene. Tomato considered as both source and sink limitation crop. There is a scope to enhance source and sink activity of tomato by using phyto-chemicals with nutrients. The supply of photo-assimilates for growth and differentiation during plant development originates from leaves and the demand for photosynthates changes as plants grow, mature and senescence (Noushina *et al.* 2011) [21]. Umesh *et al.* (2015) [27] reported that flower and fruit drop was higher due to lesser translocation of photo-assimilates from source to sink. Among the major causes accounting for flower and fruit drop are self-incompatibility, inadequate pollination, nutritional deficiency, water stress, pest and disease infestations and hormonal imbalances (Singh *et al.* 2008) [24].

Flowers require an endogenous hormonal stimulation to set fruit, especially sufficient levels of auxin and gibberellic acid. Parmer *et al.* (2016) [22] found that CCC treated plant recorded the highest fruit weight, total number of fruits and fruit yield in tomato.

Nisar *et al.* (2001) [20] found that the foliar application of gibberellic acid (60 mg / lit) recorded highest fruit yield of 26.84 t ha^{-1} compared to control (15.31 t ha^{-1}) in tomato. Naphthalene acetic acid (NAA) known to increase membrane permeability in plant cells which might facilitate accelerated breakdown of organic acids stored in cell vacuoles with consequent increase in total soluble solids content and reduced fruit drop by 57% compared to control (Bright, 2010) [6]. Application of nitrogen promotes vegetative growth and fruit yield of tomato, and later application in the growing stages favours fruit development, thus nitrogen has a dramatic effect on tomato growth and development (Hokam *et al.* 2011) [13]. Asit and Abdullah (2011) [4] reported that the foliar application of 10000 ppm urea gave the highest tomato fruit yield than the control. Similarly, application of phosphorus is an important nutrient for tomato plant growth and development, a deficiency of phosphorus leads to reduced growth and yield (Hochmuth *et al.* 2009) [12]. Foliar spray of 100 ppm salicylic acid increased the specific leaf weight by 32.8% over control in tomato (Sivakumar *et al.* 2018) [25]. Based on this background, the study was conducted to increase the sink activity (yield) of tomato by using phyto-chemicals with nutrients.

Materials and Methods

The experiment was conducted at field number A18 of Regional Research Station, Paiyur during summer irrigated 2018. Transplanting was done with the spacing of 60 x 45 cm and the plot size of 15 m^2 with tomato variety PKM 1. Crop was supplied with fertilizers and other cultivation operations including plant protection measures were carried out as per the recommended package of practices of Tamil Nadu Agricultural University, Coimbatore. Phyto-chemicals with urea and MAP solutions were prepared and the foliar spray was given at 30 and 60 days after transplanting. The treatments include control, urea (2%), urea (2%) + NAA (20 ppm), urea (2%) + CCC (200 ppm), urea (2%) + GA_3 (20 ppm), urea (2%) + salicylic acid (100 ppm), MAP (2%), MAP (2%) + NAA (20 ppm), MAP (2%) + CCC (200 ppm), MAP (2%) + GA_3 (20 ppm) and MAP (2%) + salicylic acid (100 ppm). The physiological parameters like chlorophyll and soluble protein contents were calculated between 75th and 90 days after transplanting. The experiment comprises eleven treatments and three replications with adopting statistics of randomized block design.

Chlorophyll content was estimated by using 80% acetone by adopting the procedure of Arnon (1949) [2] and the content was expressed as mg g^{-1} of fresh weight. Soluble protein content of leaf was estimated as per the method of Lowry *et al.* (1951) [16]. 250 mg of leaf sample was weighed and macerated with 10 ml of phosphate buffer solution. The content was centrifuged at 3000 rpm for 10 minutes and the supernatant was collected and made up to 25 ml. 1 ml of the supernatant was pipette out to a test tube and 5 ml of alkaline copper tartrate reagent and 0.5 ml of folin reagent were added. The colour intensity was measured at 660 nm in spectrophotometer and the amount of soluble protein present in the sample was calculated by using bovine serum albumin as standard and expressed as mg g^{-1} fresh weight.

Ripened fruit samples were analyzed for the ascorbic acid content, using 2, 6 - dichlorophenol indophenol dye titrimetrically as per the protocol given by AOAC (2000) [3]. Two gram of sample was blended with 10 ml of 4 per cent oxalic acid and filtered through muslin cloth. Two ml of extract titrated against 2, 6 - dichlorophenol indophenol dye till the pink colour end point which persisted for at least 15 seconds (TV_2). Similar procedure was followed against standard solution made in 4 per cent oxalic acid to get standard titre value (TV_1). The ascorbic acid content in the fruit was calculated by using following formula.

$$\text{Ascorbic acid} = \frac{\text{Ascorbic acid in standard} \times TV_2 \times \text{total sample volume}}{\text{Volume taken} \times TV_1 \times \text{weight of the sample}} \times 100$$

The total weight of fruits harvested from each plot of all picking was added and average yield per plot was worked out and expressed in tones per hectare. The data on various parameters were analyzed statistically as per the procedure suggested by Gomez and Gomez (1984) [10].

Results and Discussion

Physiological traits

Chlorophyll content is a key factor affecting the performance of plant photosynthesis through efficient light absorption (Taiz and Zeiger, 2006) [26]. Among the photosynthetic pigments, chlorophyll is major pigment which directly involves photosynthesis and related to assimilate production and ultimately yield. In the present study, foliar spray of 2% urea with 100 ppm salicylic acid registered higher chlorophyll content of 2.36 mg g^{-1} which is on par with urea + GA_3 (2.35), urea + CCC (2.34) and MAP + salicylic acid (2.32).

An increment of 31.8% chlorophyll content was observed by urea + SA compared to control (Table 1). Compared with two nutrients, urea showed its supremacy on chlorophyll content might be due to, nitrogen (urea) involvement in the chlorophyll formation compared to phosphorus (MAP). Nitrogen is part of the enzymes associated with chlorophyll synthesis and the chlorophyll concentration reflects relative crop N status and yield level (Chapman and Barreto, 1995) [8]. Among the phyto-chemicals, salicylic acid showed its domination on increment of chlorophyll content. Foliar application of SA can be fruitful in increasing the pigment contents in wheat (Hayat *et al.* 2005) [11]. The present study confirms with the earlier findings.

The soluble protein content of the leaf, being a measure of rubisco activity is considered as an index for photosynthetic efficiency of crop plants. Rubisco enzyme forms nearly 80 per cent of the soluble proteins in leaves of many plants (Joseph *et al.* 1981) [14]. Diethelm and Shibles (1989) [9] reported that the rubisco content per unit leaf area was positively correlated with that of soluble protein content of the leaf. Among the treatments, foliar spray of 2% urea with 100 ppm SA registered higher soluble protein content of 12.9 mg g^{-1} which is on par with MAP + salicylic acid (12.8 mg g^{-1}) (Table 1). The positive effect of nitrogen and phosphorus on soluble protein might be due to, both the nutrients involved in amino acids and protein synthesis. Chandra *et al.* (2007) [7] reported that application of salicylic acid increased the soluble protein content of cowpea plants. This can be attributed to the role of salicylic acid to improve membrane permeability, absorption and utilization of mineral nutrients.

Number of flowers

The higher number of flowers per plant (46) was recorded by urea + GA_3 followed by MAP + GA_3 (43.3) might be due to higher source growth and activity by the action of gibberellic acid while control recorded least in number (33.3) (Fig. 1). Muhammad *et al.* (2016) [19] found that the application of GA_3 at the rate of 250 mg L^{-1} recorded highest number of flowers in chrysanthemum compared to rest of the treatments. The most characteristic effects of GA_3 are increase in internode length, leaf growth and increase in number of flowers (Taiz and Zeiger, 2006) [26]. This was the reason behind that the irrespective of the nutrients in the present study, GA_3 dominated its action on number of flowers. The present study corroborated with the earlier findings. Compared two nutrients used in this study, the role of nitrogen on flower number is superior than MAP.

Table 1: Effect of phyto-chemicals on physiological parameters, yield and quality of tomato

Treatments	Chlorophyll (mg g^{-1})	Soluble protein (mg g^{-1})	Fruit yield (t ha^{-1})	Ascorbic acid (mg 100 g^{-1})
T_1: Control	1.79	11.7	28.89	24.5
T_2: Urea 2%	2.31	12.3	29.58	24.7
T_3: T_2 + NAA 20 ppm	2.28	12.1	30.47	24.6
T_4: T_2 + CCC 200 ppm	2.34	12.5	30.71	26.1
T_5: T_2 + GA_3 20 ppm	2.35	12.3	29.58	24.7
T_6: T_2 + SA 100 ppm	2.36	12.9	32.42	27.0
T_7: MAP 2%	2.12	11.8	29.18	25.0
T_8: T_7 + NAA 20 ppm	2.10	12.0	30.42	26.0
T_9: T_7 + CCC 200 ppm	2.19	12.3	30.69	25.7
T_{10}: T_7 + GA_3 20 ppm	2.17	12.1	29.93	24.8
T_{11}: T_7 + SA 100 ppm	2.32	12.8	32.07	26.7
SEd	0.055	0.309	0.809	0.626
CD (P=0.05)	0.109	0.624	1.719	1.250

Yield

Among the treatments, foliar spray of 2% urea along with 100 ppm salicylic acid showed its supremacy by recording higher fruit yield of 32.42 t ha^{-1} followed by MAP + SA (32.07 t ha^{-1}) compared to control (28.89 t ha^{-1}). Even though, the number of flowers was positively enhanced by the application of urea + GA_3, higher yield was recorded by urea + salicylic acid. This might be due to higher translocation of photo-assimilates from source to sink by the application of urea + salicylic acid. Foliar application of 100 ppm salicylic acid significantly increased the leaf area, total dry weight, net assimilation rate, specific leaf weight, and yield in maize (Amin *et al.* 2013) [1]. Present study confirms the earlier findings.

Quality traits

Ascorbic acid is a water-soluble, antioxidant vitamin. It is used on a large scale as antioxidant in food and drinks. Due to its content variation caused by the thermal liability, ascorbic acid represents an important quality indicator that contributes to the antioxidant properties of food (Popa *et al.* 2010) [23].

In the present study foliar application of phyto-chemicals with nutrients enhanced the ascorbic acid content compared to control (Table 1). Among the treatments, urea + SA registered higher ascorbic acid content (27.0 mg 100 g^{-1}) while control recorded lower (24.5 mg 100 g^{-1}).

Mahdi *et al.* (2012) [17] reported that the application of salicylic acid (10^{-2} M) increased the amount of ascorbic acid in the fruits of tomato plants and significantly had higher ascorbic acid content (32.5 mg per 100 g of fruit) compared to control plants (24 mg per 100 g fruit). These results suggest that foliar application of salicylic acid may improve quality of tomato fruits. The present study confirms the earlier findings.

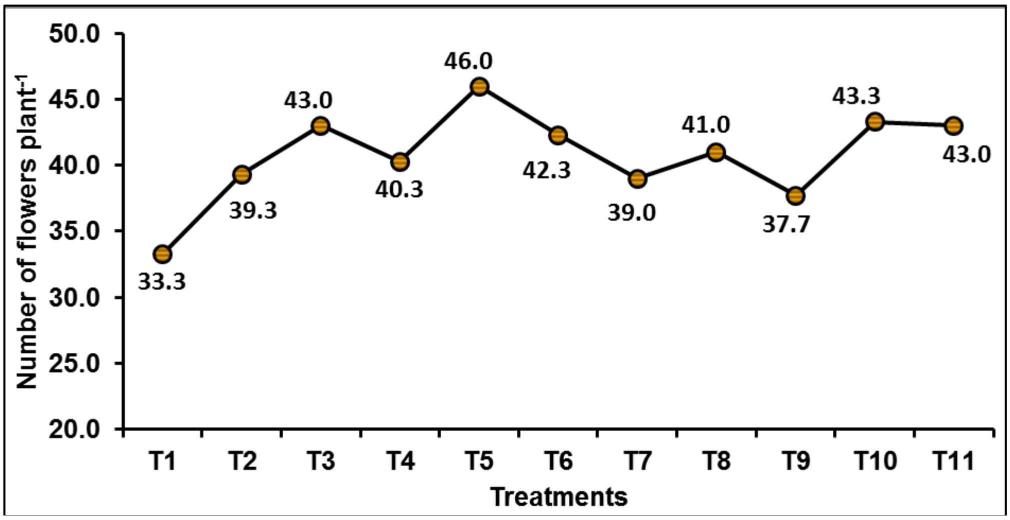

Fig 1: Effect of phyto-chemicals with nutrients on number of flowers in tomato

T_1 – Control; T_2 - urea (2%); T_3 - urea (2%) + NAA (20 ppm); T_4 - urea (2%) + CCC (200 ppm); T_5 - urea (2%) + GA_3 (20 ppm); T_6 - urea (2%) + salicylic acid (100 ppm); T_7 - MAP (2%); T_8 - MAP (2%) + NAA (20 ppm); T_9 - MAP (2%) + CCC (200 ppm); T_{10} - MAP (2%) + GA_3 (20 ppm); T_{11} - MAP (2%) + salicylic acid (100 ppm).

Sugar content is one of the major factors for the flavour of tomato fruits and balanced levels of sugars with acid are desired. Both, the sugar and acid contents are important traits for breeding (Bai and Lindhout, 2007) [5] and quality assessment. In the present study, an increment of 11.35% of total sugars was registered by the foliar application of urea + SA followed by MAP + SA (7.06%) which is on par with CCC with urea and MAP (Fig. 2).

Foliar application of SA with 10^{-4} molar concentration enhanced the average of total sugar, sucrose, glucose and fructose in tomato fruits regard to control plant (Maryam *et al.* 2014) [18]. Keshavarz *et al.* (2011) [15] expressed on a survey that foliar application by SA in growth period of *Brassica napus* increase soluble sugars. Hence, the SA causes the accumulation of sugars and higher concentration of mannose, xylose and glucose were observed in vulnerable variety of *Brassica napus* treated with 400 micro-molar concentration of SA.

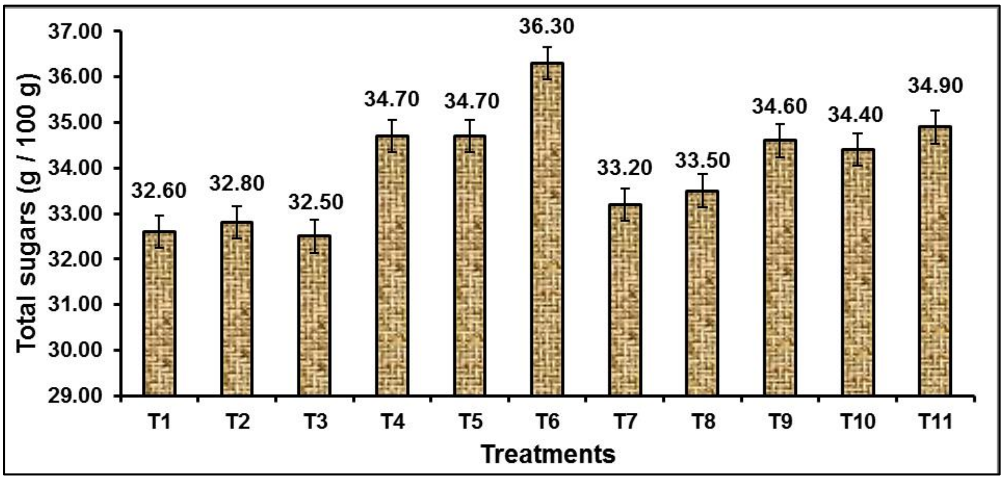

Fig 2: Effect of phyto-chemicals with nutrients on total sugars in tomato fruit

T_1 – Control; T_2 - urea (2%); T_3 - urea (2%) + NAA (20 ppm); T_4 - urea (2%) + CCC (200 ppm); T_5 - urea (2%) + GA_3 (20 ppm); T_6 - urea (2%) + salicylic acid (100 ppm); T_7 - MAP (2%); T_8 - MAP (2%) + NAA (20 ppm); T_9 - MAP (2%) + CCC (200 ppm); T_{10} - MAP (2%) + GA_3 (20 ppm); T_{11} - MAP (2%) + salicylic acid (100 ppm).

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