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Impact of phyto-chemicals with nutrients on growth analytical traits and yield of tomato

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Abstract
Field experiment was conducted to study the impact of phyto-chemicals (naphthalene acetic acid - 20 ppm, chloro choline chloride - 200 ppm, gibberellic acid - 20 ppm and salicylic acid - 100 ppm) with nutrients nitrogen (2% urea) and phosphorus (2% mono ammonium phosphate) alone and combinations on growth analytical parameters and yield of tomato by foliar spray at 30 and 60 days after transplanting. The growth analytical parameters like leaf area index, leaf area duration, specific leaf weight, net assimilation rate and crop growth rate, and yield were estimated. Foliar spray of 2% urea with 20 ppm gibberellic acid registered higher leaf area index (0.89), leaf area duration (27 days), specific leaf weight (0.0874), net assimilation rate (0.642) and crop growth rate (16.20). However, the highest fruit yield of 33.87 t ha^{-1} was recorded by foliar spray of 2% MAP + 100 ppm salicylic acid followed by 2% urea with 20 ppm gibberellic acid (32.13 t ha^{-1}).

Keywords: Tomato, urea, MAP, NAA, GA_3, CCC, salicylic acid, LAD, CGR

Introduction

Plant growth and development are normally limited by photosynthetic resources called. ‘source-limitation’. The source activity drives the sink metabolism and in turn is related to carbon and nitrogen metabolism. 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) [10]. Umesh *et al.* (2014) [19] 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) [15]. Flowers require an endogenous hormonal stimulation to set fruit, especially sufficient levels of auxin and gibberellic acid. Parmer *et al.* (2016) [11] found that CCC treated plant recorded the highest number of branches per plant, dry weight of shoot, fruit weight, total number of fruits and fruit yield in tomato.

Foliar spray of gibberellic acid (GA_3) and auxin can trigger fruit set even without pollination and can induce parthenocarpic fruit development. GA_3 is known to play a crucial role in the sugar metabolism of plants. Gibberellins actively participate in the hydrolysis of sucrose and starch. They promote the activity of the enzyme, invertase, which catalyzes the hydrolysis of sucrose, thereby yielding glucose and fructose. Auxin like 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. Bright (2010) [3] reported that the exogenous application of GA_3 increased tomato plant height and increased the number of inflorescences by 28% as compared to control. Foliar spray of NAA reduced fruit drop by 57% compared to control. 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) [7]. 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) [6]. Foliar spray of 100 ppm salicylic acid increased the specific leaf weight by 32.8% over control in tomato (Sivakumar *et al.*, 2018) [16]. Tomato (*Solanum lycopersicom*) belongs to the family solanaceae and important vegetable crop with good source of vitamins A, B and C. The popularity of tomato is rising among consumers because of its good taste, high level of lycopene and beta-carotene, which are good anti-oxidants. Based on this background, the study was conducted to increase the source (growth analytical traits) and sink activity (yield) of tomato by using phyto-chemicals with nutrients.

Materials and Methods

The experiment was carried out at field number A18 of Regional Research Station, Paiyur during kharif 2017. 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 recommended package of practices of Tamil Nadu Agricultural University, Coimbatore. Phyto-chemicals with urea and MAP solution 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 growth analytical parameters like leaf area index (LAI), leaf area duration (LAD), specific leaf weight (SLW), crop growth rate (CGR) and net assimilation rate (NAR) were calculated between 75th and 90 days after transplanting. The experiment comprises eleven treatments and three replications with adopting statistics of randomized block design.

Leaf area index was calculated by employing the formula of Williams (1946) [21] as follows. LAI = Leaf area per plant / Ground area occupied by the plant. Leaf area duration was determined by using the formula of Power *et al.* (1967) [13] as follows and expressed in days.

$$LAD = \frac{L_1 + L_2}{2}(t_2 - t_1)$$

Where, L_1 = LAI at first stage, L_2 = LAI at second stage, $t_2 - t_1$ = Time interval in days

Specific leaf weight was calculated by using the formula suggested by Pearce *et al.* (1968) [12] as follows. SLW = Leaf dry weight / leaf area. Watson (1958) [20] suggested the following formula was used to calculate crop growth rate.

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

Where, W_2 and W_1 = Whole plant dry weight at t_2 & t_1 respectively; $t_2 - t_1$ = Time interval; P = Spacing in m^2. Net assimilation rate was worked out by using following formula proposed by Williams (1946) [21].

$$NAR = \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1} \times \frac{W_2 - W_1}{t_2 - t_1}$$

Where,
Log e L_2 = Natural log of leaf area at time t_2
Log e L_1 = Natural log of leaf area at time t_1
L_2 & L_1 =Leaf area at t_2 & t_1 respectively.
W_2 & W_1 = Plant dry weight at t_2 & t_1 respectively
$t_2 - t_1$ = Time interval

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 tonnes per hectare. The data on various parameters were analyzed statistically as per the procedure suggested by Gomez and Gomez (1984) [5].

Results and Discussion

Leaf area index is one of the principal aspects influencing leaf net photosynthesis of the crops. The capacity of a leaf canopy to intercept light and fix carbon is measured by the leaf area index. LAI is mainly decided by the source strength. In the present study, foliar spray of 2% urea with 20 ppm GA_3 registered higher LAI of 0.89 followed by urea + salicylic acid (0.87) (Fig. 1). Compared with two nutrients, urea showed its supremacy on LAI might be due to nitrogen involvement in the vegetative growth compared to phosphorus (MAP). Among the phyto-chemicals, GA_3 showed its domination on LAI due to enhancement of vegetative growth through increased plant height by cell elongation. Ajmn *et al.* (2016) [1] found that foliar spray of GA_3 at the concentration of 33.33 ppm recorded higher leaf area and leaf area index compared to control in cowpea. The present study confirms with the earlier findings.

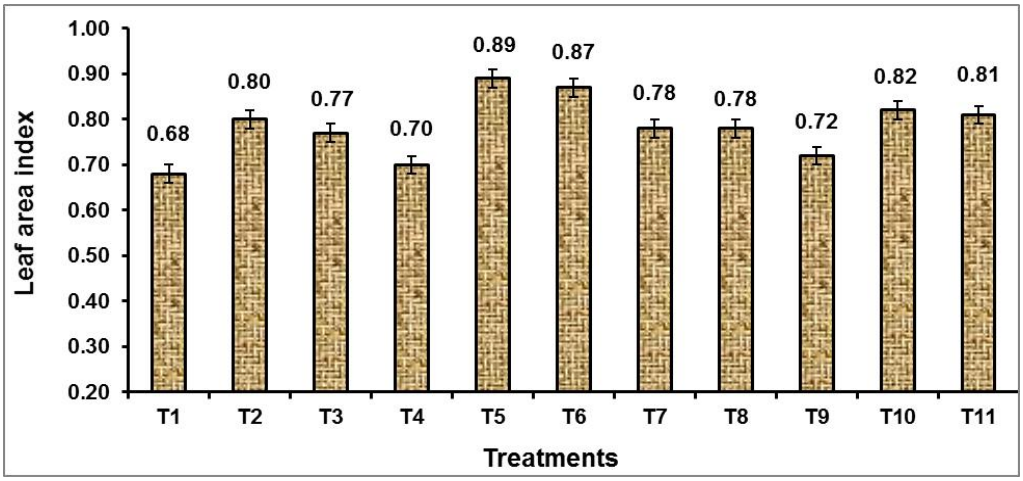

Fig 1: Impact of phyto-chemicals with nutrients on leaf area index of tomato

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).

The integration of leaf area index with time called as leaf area duration. Among the treatments, control recorded lower LAD value of 20 days and foliar spray of 2% urea with 20 ppm GA_3 registered higher LAD of 27 days followed by urea +

salicylic acid (26 days) and MAP + GA_3 (25 days) (Table 1). The higher leaf area duration by urea + GA_3 might be due to higher leaf area index. Among the phyto-chemicals, foliar spray of CCC showed less LAD might be due to lower plant height and leaf area by its growth inhibitor nature which act as anti-gibberellin. In absence of nitrogen, gibberellic acid increased the leaf area duration, but this increase was not associated with increase in yield. With nitrogen most of the difference in leaf area duration caused by mineral nutrition was associated with lateral stem leaves. GA_3 at 50 ppm increased the leaf area duration in okra when applied as foliar spray after 80 days of sowing (Surendra *et al.*, 2006) [17]. Hunkova *et al*. (2011) [8] reported that LAD parameter reflects the ability of plants to create and maintain the green leaf area for the longest time. It is calculated as a conjunction of green leaf area size and it's duration.

Table 1: Impact of phyto-chemicals on growth analytical parameters and yield of tomato

Treatments	LAD (Days)	SLW (mg cm^{-2})	CGR (g m^{-2} d^{-1})	Fruit yield (t ha^{-1})
T_1: Control	20	0.0666	12.35	28.38
T_2: Urea 2%	24	0.0786	14.56	28.42
T_3: T_2 + NAA 20 ppm	23	0.0760	14.08	28.49
T_4: T_2 + CCC 200 ppm	21	0.0675	12.70	28.62
T_5: T_2 + GA_3 20 ppm	27	0.0874	16.20	32.13
T_6: T_2 + SA 100 ppm	26	0.0852	15.79	31.78
T_7: MAP 2%	23	0.0762	14.14	29.44
T_8: T_7 + NAA 20 ppm	23	0.0764	14.16	28.38
T_9: T_7 + CCC 200 ppm	22	0.0704	13.04	30.56
T_{10}: T_7 + GA_3 20 ppm	25	0.0804	14.90	31.24
T_{11}: T_7 + SA 100 ppm	24	0.0794	14.71	33.87
SEd	0.484	0.0016	0.324	0.748
CD (P=0.05)	0.972	0.0033	0.656	1.516

Specific leaf weight is an indicator of the photo-assimilates production capacity of the plants per unit leaf area. It is the ratio between leaf weight and leaf area. SLW reflects the thickness of leaf and photo-assimilates accumulation per unit leaf area. Foliar spray of urea with GA_3 recorded higher SLW of 0.0874 mg cm^{-2} which is on par with urea + salicylic acid (0.0852 mg cm^{-2}) followed by MAP + GA_3 (0.0804 mg cm^{-2}). The lowest SLW of 0.0666 mg cm^{-2} was registered by control (Table 1). Krishna Surendar *et al.* (2013) [9] reported that the significant increase in the leaf area index and specific leaf weight due to basal application of nitrogen 25 kg per hectare along with foliar spray of 2% urea compared to control. Present study corroborated with the earlier findings. Foliar spray of nitrogen in the form of urea along with GA_3 increased the SLW up to 31.23% might be due to the enhancement of photosynthesis by maintaining chlorophyll and accumulation photo-assimilates in the leaf.

Crop growth rate denotes that dry matter accumulation per unit land area and unit time. Maintenance of CGR is an essential growth analytical trait which decides the yield of crop plants. Among the treatments, urea + GA_3 recorded highest CGR value of 16.20 g m^{-2} d^{-1} followed by urea + salicylic acid (15.79 g m^{-2} d^{-1}), MAP + GA_3 (14.90 g m^{-2} d^{-1}) and MAP + salicylic acid (14.71 g m^{-2} d^{-1}) compared to control (12.35 g m^{-2} d^{-1}). Foliar spray of urea + GA_3 increased the CGR value up to 27.85% compared to control (Table 1). Surendra *et al.* (2006) found that the foliar spray of GA_3 (50 ppm) at 80 days after sowing recorded maximum crop growth rate compared to control. Fayza *et al.* (2016) [4] registered maximum crop growth rate by the application of nitrogen along with foliar spray of salicylic acid in maize. The positive effect of urea on vegetative growth is mainly due to its role of nitrogen as the most important primary nutrient which involved in building up of plant organs. The increased CGR by foliar spray of salicylic acid might be due to increase the level of cell division which caused an increase in plant growth (Sakhabutdinova *et al.*, 2003) [14]. Net assimilation rate is an appropriate parameter for the measurement of net photosynthesis of leaves in a crop. In the present study, the highest NAR value of 0.642 mg cm^{-2} d^{-1} was recorded by foliar spray of urea (2%) + GA_3 (20 ppm) followed by MAP (2%) + salicylic acid (100 ppm) which recorded 0.583 mg cm^{-2} d^{-1} (Fig. 2). Foliar application of 100 ppm salicylic acid significantly increased the leaf area, total dry weight, leaf area index, net assimilation rate, specific leaf weight, and yield in maize (Amin *et al.*, 2013) [2]. Tesfaye (2009) [18] explained that low phosphorus supply reduced the net assimilation rate in potato. Present study confirms the earlier findings.

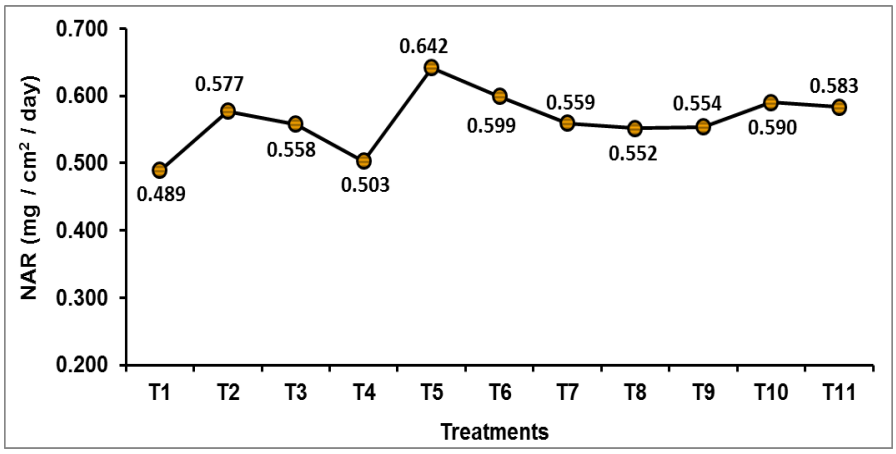

Fig 2: Impact of phyto-chemicals with nutrients on net assimilation rate of tomato

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).

Among the treatments, foliar spray of 2% MAP along with 100 ppm salicylic acid showed its supremacy by recording higher fruit yield of 33.87 t ha^{-1} followed by urea + GA_3 (32.13 t ha^{-1}), urea + salicylic acid (31.78 t ha^{-1}) and MAP + GA_3 (31.24 t ha^{-1}) compared to control (28.38 t ha^{-1}). Even though, the growth analytical traits were positively enhanced by the application of urea + GA_3, higher yield was recorded by MAP + salicylic acid. This might be due to higher translocation of photo-assimilates from source to sink by the application of MAP + salicylic acid. However, the yield increment by the application of MAP + salicylic acid should be confirmed by physiological and biochemical analysis.

Conclusion

Foliar spray of 2% MAP + 100 ppm salicylic acid at 30 and 60 days after transplanting increased the yield up to 19.34% followed by urea (2%) + GA_3 (20 ppm) compared to control. However, the growth analytical traits like LAI, LAD, SLW, CGR and RGR were enhanced by urea (2%) + GA_3 (20 ppm) compared with other treatments.

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