

Original Research Article

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Effect of PPFM and PGRs on Root Characters, TDMP, Yield and Quality of Tomato (*Solanum lycopersicum*) under Drought

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ABSTRACT

Water is precious and water scarcity is the major cause of drought. Indian agriculture primarily depends on irrigation facilities and drought is threatening when the country's population is increasing rapidly. Due to climate change, drought adversely affect on agricultural production by lowering the produce. An experiment was conducted to assess the impact of PPFM (Pink Pigmented Facultative Methylo-troph) and PGRs on alleviating the drought stress effects on tomato through root characters, yield and quality. Pot culture experiment was carried out in tomato variety PKM 1 with foliar spray of PPFM (1%), PPFM (2%), PPFM (3%) and growth regulators like brassinolide (1 ppm), salicylic acid (100 ppm), benzyl amino purine (100 ppm) and gibberellic acid (10 ppm) under drought condition created based on field capacity of soil. 50 per cent field capacity was maintained throughout the growth period for induction of drought and 100 per cent field capacity maintained as absolute control. The study indicated that the PPFM and PGRs could be effectively improving drought tolerance capacity of tomato crop under drought. Among the PGRs and different concentrations of PPFM used, PPFM (2%) was found to superior in improving root characters and yield. The highest root length of 25.9 cm was registered by PPFM (2%) which has the ability to protect the plant under drought. Foliar spray of 2% PPFM recorded highest specific leaf weight (5.96) followed by 100 ppm salicylic acid (5.66). The higher fruit yield of 552.9 g was maintained by PPFM (2%) followed by brassinolide (509.4) under drought. PPFM (2%) registered its supremacy on higher lycopene content (5.92) followed by brassinolide (5.88).

Keywords

PPFM, Brassinolide, Salicylic acid, Root length, SLW, Yield, Lycopene, Tomato

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Introduction

Tomato (*Solanum lycopersicom*) belongs to the family solanaceae and important vegetable crop w is a 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. Although tomato is a

day neutral plant, which is highly susceptible to high temperature (Malik and Bashir, 1994) and drought. India is the second largest producer of tomato accounting for 11.10% of the world's production. According to the fifth assessment report of IPCC (2014), drought is the significant impact of current climate related extremes. In India, drought is a regular problem which affects agriculture production

and life of animals and humans frequently. Water is the most limiting factor for plant growth. If plants do not receive adequate water, the resulting drought stress can reduce growth more than all other environmental stresses combined (Khan *et al.*, 2015).

Drought is the most important environmental stress in agriculture and many efforts have been made to improve crop yield under drought. While natural selection has favoured mechanisms for adaptation and survival, breeding activity has directed selection towards increasing the yield of crops. Meanwhile, foliar application of PGRs can be used to mitigate the negative effect of drought on crops through physiological approaches.

Farjam *et al.*, (2013) suggested that the foliar spray of salicylic acid significantly increased the proline content and improves drought tolerant capacity of chick pea under drought stress condition. Foliar spray of PPFM (2%) was found to superior in improving relative water content, photosynthetic rate, SPAD value, proline content ultimately improve the drought tolerant capacity in tomato (Sivakumar *et al.*, 2017). Extensive research over the years' has established stress-impact-mitigating role of brassinosteroids and associated compounds in different plants exposed to various abiotic stresses such as high temperature and drought (Mahesh *et al.*, 2013). Chandrasekaran *et al.*, (2017) reported that the PPFM (2%) and brassinolide (1 ppm) treatments were found to superior in improving germination associated traits, stress tolerant index and anti-oxidant enzyme catalase activity which have the ability to protect the plant under abiotic stress condition. Peleg *et al.*, (2011) found over expression of *ipt* gene which is responsible for cytokinin synthesis improves the drought tolerance in different plants. Hence, the present study was conducted to mitigate the drought effect on tomato by using PPFM and

PGRs through assessing root characters, yield and quality.

Materials and Methods

The experiment was carried out in the pot culture under glass house condition. Red sandy soil was used for pot culture experiment. Soil mixture was prepared by using red soil, vermicompost and sand in the ratio of 3:2:1. Drought was imposed at first day after transplanting onwards by maintaining soil moisture at 50 per cent field capacity for drought stress. The experiment was laid out in completely randomized block design with three replications. The treatments like absolute control (100% FC), Control (50% FC), PPFM (1%), PPFM (2%), PPFM (3%), brassinolide (1 ppm), salicylic acid (100 ppm), benzyl amino purine (100 ppm) and GA₃ (10 ppm) were used for this experiment. PPFM and PGRs treatments were given as foliar spray at 25 and 45 days after transplanting.

The plant was uprooted from the pot and the root was taken with minimum damage and the length from the cotyledonary node to the root tip was measured and expressed as cm. The root volume was estimated by water displacement method.

Individual plant roots were immersed in known volume of water and the amount of water displaced was measured and expressed in cubic centimeter. Uprooted plant samples, after washing the root portion, were first shade dried and then oven dried at 80⁰C for 48 hours. Transverse hand sections, approximately 0.2 to 0.5 mm thickness were made with a razor blade from roots and taken for Scanning Electron Microscopy (SEM) using a FEI QUANTA 250 ESEM. In the anatomical cross sections the length and width of treachery cells were measured.

The dry weight of the whole plant was recorded and expressed as g plant⁻¹. Specific leaf weight was calculated by using the formula of Pearce *et al.*, (1968) and expressed in mg cm⁻². The total weight of fruits harvested from each plant of all picking was added and average yield per plant was worked out and expressed in gram per plant.

The total soluble content in the pulp was determined by using a hand refractometer and expressed in °Brix. Lycopene content of the fruit was estimated by using petroleum ether and OD of the extract was measured at 503 nm in UV-VIS spectrophotometer using petroleum ether as blank (Ranganna, 1986). Ripened fruit samples were analyzed for the ascorbic acid content, using 2, 6 - dichlorophenol indophenol dye titrimetrically as per AOAC (2000).

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 (TV₂). Similar procedure was followed against standard solution made in 4 per cent oxalic acid to get standard titre value (TV₁). The ascorbic acid content in the fruit was calculated by using following formula.

Ascorbic acid =

$$\frac{\text{Ascorbic acid in standard} \times \text{TV}_2 \times \text{Total sample volume}}{\text{Volume taken} \times \text{TV}_1 \times \text{Weight of the sample}} \times 100$$

The data on various parameters were analyzed statistically as per the procedure suggested by Gomez and Gomez (1984). Wherever the treatment differences are found significant, critical differences were worked out at five per cent probability level and the values were furnished.

Results and Discussion

Impact of PPFM and PGRs on root characters under drought

Root length plays a major role in the absorption of water and nutrients necessary for normal plant growth. The reduction of root growth is a result of the inhibition of cell cycle progression and reduction in root apical meristem size (West *et al.*, 2004). The present investigation showed that the root length was decreased up to 51.19 per cent under drought stress over absolute control. The application of PGRs invariably reduced the per cent reduction of root length under drought which leads to increasing the water uptake.

The maximum root length was recorded in absolute control (27.90 cm) and minimum in control of 13.50 cm. Among the treatments, PPFM (2%) marked the highest root length of 25.90 cm, followed by brassinolide (25.20 cm) and salicylic acid (22.93 cm). Root length was increased up to 26.34 per cent by PPFM (2%) higher than control followed by brassinolide (22.93%) (Table 1). Chandrasekaran *et al.*, (2017) found that the treatment with PPFM (2%) recorded higher root length followed by gibberellic acid and salicylic acid in tomato. This increment by PPFM might due to, methylbacterium are capable to generate plant growth regulators such as auxin and cytokinin (Ivanova *et al.*, 2000) which induce cell division and cell elongation. Clouse (2011) reported that application of brassinosteroids increase the root growth under drought might be due to it stimulates ethylene biosynthesis and triggers ethylene responses in roots.

Highest root volume was observed in absolute control (122.80 cc) whereas in control (97.90 cc) recorded lowest (Table 1). Among the PGRs, salicylic acid (119.70 cc) registered highest root volume followed by brassinolide

(118.90 cc) and PPFM (2%) treatment (117 cc). Salicylic acid exhibited increased root volume up to 22.33 per cent compared to control under drought condition followed by brassinolide (21.45%). The foliar spray of PGRs and PPFM helps to alleviate drought with improving the lateral root growth which increased the root volume.

Roots, the primary organs for the absorption of water and minerals, ironically offer the greatest resistance to liquid water flow in the soil-plant interphase simply to regulate the absorption process with minimum energy (Rieger and Litvin, 1999). In the present study showed pictorial representation of SEM root cross section, whole view of the root showed smaller in size ($61.56 + 55.65 \mu\text{m}$) observed in control compared to absolute control ($104 + 61.6 \mu\text{m}$). Changes in the size of tracheary elements and change in their organization as aggregation of xylem vessel elements was obvious (Wolf *et al.*, 2012). Similarly, present study, PPFM (2%) treatment ($94.32 + 81.09 \mu\text{m}$) showed larger tracheary element size in terms of length and width grown under drought stress (Fig. 1) followed by brassinolide ($63.15 + 56.79 \mu\text{m}$).

One of the most functional aspects related to root anatomy is water and nutrient transport capacity, because it is highly influenced by the number and size of the water conducting elements (Steudle and Peterson, 1998). Root water uptake of the whole plant is a function of both hydraulic conductivity and water potential gradient across the root or the whole plant. Crop plants are better equipped with an appropriate type of anatomy, largely constitutive in nature, to cope with the surrounding environment (Rieger and Litvin, 1999). However, Purushothaman *et al.*, (2013) reported that the number and size of the xylem vessels and other xylem components seem to increase with water scarcity.

Impact of PPFM and PGRs on TDMP and SLW under drought

The analysis on the total dry matter production per plant revealed that absolute control have more dry matter production compared to drought plant. In the present study, TDMP was decreased up to 27.70 per cent by drought when compared to absolute control (Table 1). Drought stress suppressed the plant height, leaf number, size and tillers which finally lowered the dry matter production (Khan and Abdullah, 2003). Water availability is the key factor for dry matter production in plant. Low water availability decreases water and nutrient uptake, photosynthetic rate and translocation of photo assimilates. Nahar *et al.*, (2011) showed reduction in dry matter production under water deficit condition in four tomato genotypes.

Among the PGRs and PPFM, salicylic acid showed the more TDMP of $91.06 \text{ g plant}^{-1}$ followed by brassinolide ($90.51 \text{ g plant}^{-1}$) and 2% PPFM ($88.67 \text{ g plant}^{-1}$). In the present study, it was observed that foliar spray of salicylic acid increased the TDMP by 33.54 per cent compared to control followed by brassinolide (32.73%).

Zhang *et al.*, (2008) found that application of BRs could partially alleviate the detrimental effect of water stress on growth of soybean through improving antioxidant system and promoting dry matter accumulation. Seed treatment or foliar application of chemicals like kinetin, salicylic acid increased the yield of different crops due to reduction in stress induced inhibition of plant growth and plant dry matter production (Khan *et al.*, 2003).

SLW is to assess the translocation efficiency of crop plants. Due to drought stress, 29.90 per cent of SLW was reduced when compared to absolute control. Highest specific leaf

weight of 6.08 mg cm⁻² was observed in absolute control and the lowest was recorded in control (4.26 mg cm⁻²). Among the treatments, PPFM (2%) showed higher specific leaf weight of 5.96 mg cm⁻². Among the PGRs, PPFM (2%) showed 28.52 per cent increment of SLW followed by brassinolide (Fig. 2). The enhancement of SLW by brassinolide and PPFM (2%) might be due to involvement in the translocation of photo assimilates from source to sink.

Impact of PPFM and PGRs yield under drought

Absolute control significantly recorded the highest fruit yield of 674.10 g and control recorded the least value of 300.30 g. Foliar spray of 2% PPFM documented significantly superior fruit yield of 552.90 g which is

closely followed by brassinolide (509.40 g) and salicylic acid (472.60 g). Wang *et al.*, (2003) reported that drought is a serious environmental stress which affects agriculture productivity and yield more than 50 per cent. In the present study, 64.70% of yield was reduced by drought stress (Table 2). Jaleel *et al.*, (2008) observed that drought is one of the serious environmental factor affecting yield and quality. Water stress inhibits cell enlargement and cell division ultimately reduces plant growth by affecting various physiological and biochemical processes. Yield showed positive response to PGRs and PPFM under water deficit condition. PGRs help in mitigation of water stress and reduced the per cent reduction in yield in wheat (Shah and Paulsen, 2011). In the present study, fruit yield increased up to 35.00 per cent by PPFM (2%) followed by brassinolide (24.50%).

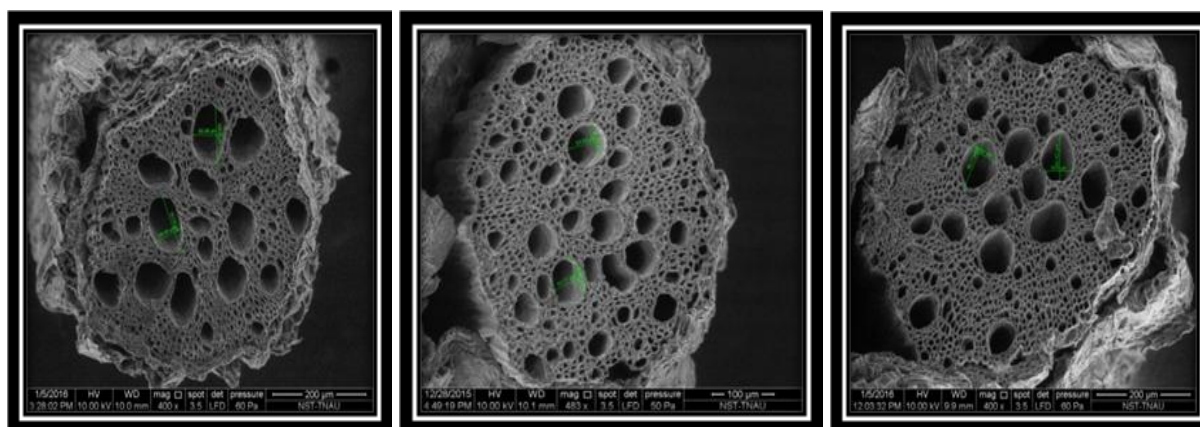
Table.1 Effect of PGRs and PPFM on root characters and TDMP of tomato under drought

S. No.	Treatments	Root length (cm)	Root Volume (cc)	TDMP (g plant ⁻¹)
1	Absolute control (100% FC)	27.90	122.80	94.27
2	Control (50% FC)	20.50	97.90	68.19
3	PPFM (1%)	22.60	101.00	66.36
4	PPFM (2%)	25.90	117.00	88.67
5	PPFM (3%)	22.10	110.90	65.49
6	Brassinolide (1 ppm)	25.20	118.90	90.51
7	Salicylic acid (100 ppm)	22.93	119.70	91.06
8	BAP (100 ppm)	21.50	108.70	74.32
9	GA ₃ (10 ppm)	22.10	106.76	76.48
	SEd	0.48	2.73	1.95
	CD (P=0.05)	1.02	5.73	4.09

Table.2 Effect of PGRs and PPFM on yield and quality parameters of tomato under drought

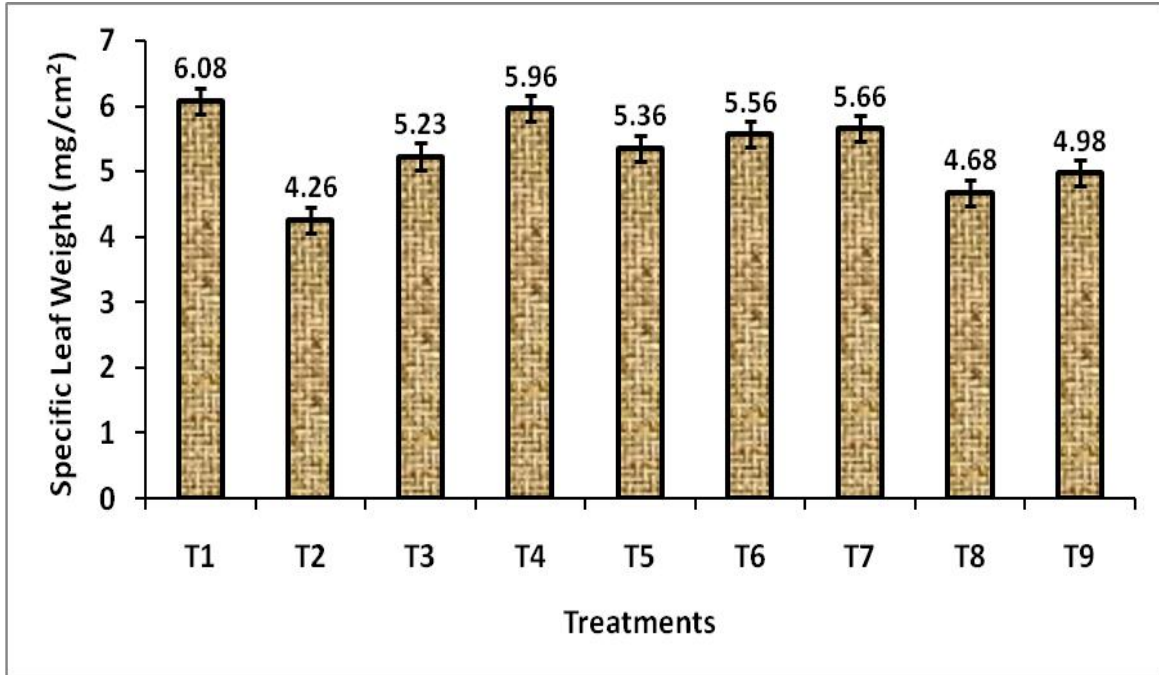
S. No.	Treatments	Fruit yield (g)	TSS (°Brix)	Ascorbic acid (mg 100 g ⁻¹)
1	Absolute control (100% FC)	674.10	6.20	28.92
2	Control (50% FC)	409.30	5.00	24.36
3	PPFM (1%)	462.40	5.60	25.93
4	PPFM (2%)	552.90	5.90	27.32
5	PPFM (3%)	428.80	5.10	25.87
6	Brassinolide (1 ppm)	509.40	6.00	24.78
7	Salicylic acid (100 ppm)	472.60	5.40	26.02
8	BAP (100 ppm)	419.20	5.80	26.65
9	GA ₃ (10 ppm)	425.60	5.10	25.34
	SEd	11.03	0.12	0.48
	CD (P=0.05)	23.18	0.24	1.02

Fig.1 Effect of PPFM on SEM root cross section of tomato under drought



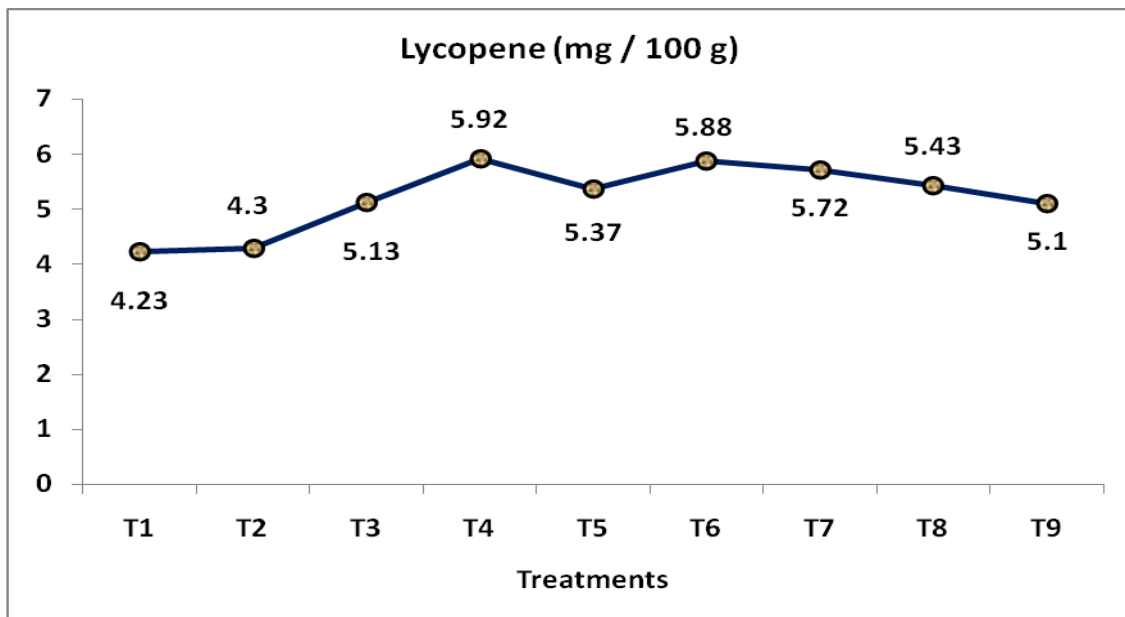
Absolute Control (100 FC) Control (50% FC) PPFM (2%) spray

Fig.2 Effect of PGRs and PPFM on specific leaf weight of tomato under drought



T₁: Absolute control (100% FC); T₂: Control (50% FC); T₃: PPFM (1%); T₄: PPFM (2%); T₅: PPFM (3%); T₆: Brassinolide (1 ppm); T₇: Salicylic acid (100 ppm); T₈: BAP (100 ppm); T₉: GA₃ (10 ppm)

Fig.3 Effect of PGRs and PPFM on lycopene content of tomato fruit under drought



T₁: Absolute control (100% FC); T₂: Control (50% FC); T₃: PPFM (1%); T₄: PPFM (2%); T₅: PPFM (3%); T₆: Brassinolide (1 ppm); T₇: Salicylic acid (100 ppm); T₈: BAP (100 ppm); T₉: GA₃ (10 ppm)

Impact of PPFM and PGRs on lycopene, ascorbic acid and TSS

Lycopene is a key quality parameter in tomato which plays an important role in biosynthesis of carotenoids. It is responsible for red color in tomato fruit and acts as an antioxidant. It has a specific role in defense mechanism against environmental stress by scavenging peroxy radicals and quenching singlet oxygen. Giannakoula and Ilias (2013) found there was a significant increase in lycopene content under drought in tomato. In the present study, 1.62 per cent of lycopene content was increased under drought compared to absolute control (Fig. 3). Among the PGRs and PPFM used, PPFM (2%) ranked first with 5.92 mg of lycopene followed by brassinolide (5.88).

However, ascorbic acid content decreased 18.72 per cent under drought stress condition over absolute control in the present experiment. In contrast, early findings by Tambussi *et al.*, (2000) who reported that the increase in ascorbic acid might be an effective strategy to protect membranes from oxidative damage in stressed condition. However, in present study, PPFM (2%) treatment increases 12.15 per cent ascorbic acid level. The similar result was found in tomato (Kumar *et al.*, 2014). Total soluble solids decreased under drought stress condition up to 24 per cent over absolute control (Table 2). Among the treatments used, brassinolide increased the TSS by 20 per cent over control followed by PPFM (2%) treatment (18%).

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