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TRIA-mediated Physio-morphological and Biochemical Growth Regulation in Maize (*Zea mays* L.) under Moisture Deficit Stress

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ABSTRACT: Triacontanol [$CH_3(CH_2)_{28}CH_2OH$] a novel plant growth regulator found in epicuticular waxes of several plants. Tricontanol (TRIA)-mediated augment in maize dry matter production as influenced by the inter-relationship between primary and secondary metabolism as well as enhanced biosynthesis of secondary metabolites. Moreover, TRIA also plays an imperative role in alleviating the moisture stress-accrued alterations in maize crops via modulating the activation of the stress tolerance mechanisms. Triacontanol (TRIA) when applied to maize plants as a foliar spray results a noteworthy augment in physio-biochemical growth and also induce drought tolerance. To explore such growth responses as well as alleviation of moisture stress in maize mediated by TRIA an exogenous application of TRIA in different concentration *viz.*, T_1 (1500ppm), T_2 (2000ppm) and T_3 (2500ppm) have been done at 30DAS, 60DAS (initiation of tasseling stage) and 90DAS under normal watering (Control that set at 100% of the field capacity) and watering at 60% field capacity (moderate drought stress). Among the three treatments, T_3 exhibited more beneficial effect to regulate the physio-biochemical growth in maize and also mitigate the drought stress followed by T_2. However, T_1 also have exhibited slight beneficial effect to mediate growth regulation as well as to improve the drought tolerance in maize.
On an overall observation, it has been concluded that TRIA can modulate physio-biochemical growth as well as improves the level of drought tolerance in maize. Maize production under drought stress is a major challenge to the grower and must require some proper management so that productivity of this crop may not be compensated under moisture deficit stress. Thus, it is recommended that TRIA must be applied for modulating maize growth under water stress and yield as well as the productivity of maize may be enhanced by the application of TRIA at an appropriate concentration and growth stages of the crop.

Keywords: Triacontanol (TRIA), morphological & physio -biochemical attributes, maize and moisture stress.

INTRODUCTION

Maize (*Zea mays* L.) is consider as most important cereal that are being used as nutritious food, fodder, and used as raw materials for industrial supply like ethanol production, bio-fuel energy etc. It is highly beneficial cereal and main ingredient in different dietary products due to its presence of high amount of carbohydrates, protein, fiber, vitamins, and minerals etc (Farooq *et al.,* 2015). Maize has the immense potentiality for wider adaptability as it is the only food cereal crop that can be grown in diverse seasons and ecologies, having high yield, quality and nutritive value, and due to these, it is popularly known as 'King of crops' and 'Queen of cereals' because of its higher genetic yield potential.

Tricontanol (TRIA) is a 30 carbon saturated long-chain primary alcohol found in epicuticular waxes of several plants having growth promoting activities when exogenously applied to number of plants. This is popularly includes in the family of Novel plant growth regulator and at as a signaling molecule. Such Tricontanol (TRIA)-mediated augment in maize growth might have due to inter-relationship between primary and secondary metabolism as well as enhanced biosynthesis of several secondary metabolites. Moreover, TRIA also plays an imperative role in regulating maize grown under drought by modulating stress tolerance mechanisms. Chibnall *et al.* (1933) was the first pioneer to isolate and identified Triacontanol [$CH_3(CH_2)_{28}CH_2OH$] as a natural component of epicuticulary waxes from *Medicago sativa* L. Later on, Ries (1985) also have been confirmed that TRIA regulate dry weight, leaf area, sugar and protein contents. TRIA enhances the dry weight, plant height, leaf area, longer and better spread of roots, early and uniform maturity, better mineral uptake, and increase water permeability, yield, and increase photosynthetic rate and photo assimilates (Haugstad *et al.,* 1983), protein, total soluble sugars, total nitrogen (Ries, 1985) and chlorophyll contents of rice, maize, tomato, soybean, ground nut and wheat seedling etc when applied as foliar.

According to Ries and Houtz (1983), some of the crops like rice and maize responds very quickly by exogenous application of TRIA within 10 minutes and imparts a pivotal role in micro-propagation of ornamental and some other plants (Reddy *et al.,* 2002; Tantos *et al.,* 2001; Gururaj *et al.,* 2007). Mandava (1979) recognized TRIA as a secondary growth regulator which cannot be included in phytohormone group and it may enhance the physiological efficiency of the cells to exploit the plant genetic potentiality of the crop up to a greater extent. TRIA enhanced the physiological activities by increasing the purity percentage of TRIA up to 99.7% as reported in rice and maize seedlings (Ries and Wert 1982).

Abiotic stress like drought is the major limiting factors that affect the maize growth from seedling to maturity as it alters the hormonal balance in plants. Such hormonal imbalances in spring wheat induced by abiotic stress like salinity could overcome by exogenous application of growth regulators (Iqbal & Ashraf 2013a, 2013b). Plant tissue water content decreases by drought-mediated response in Bell Pepper (*Capsicum annuum* L.) by reducing turgor pressure (Delfine *et al*., 2002). According to Perveen *et al*. (2010, 2012a, 2012b, 2013, 2014) TRIA has the significant beneficial effect on growth and physio-biochemical attributes of wheat grown under salinity stress and based on that it was hypothesized TRIA also may have the ability to improve the growth under water stress condition. Perveen *et al*. (2014) also established that the foliar application of TRIA regulated water homeostasis by boosting up translocation and thereby accumulation/synthesis of compatible organic solutes in wheat.

TRIA application also has been known to mediate different physio-morphological and biochemical growth responses in several crops like wheat (Ries, 1991), chickpea (Singh *et al*., 1991), soybean (Krishnan & Kumari 2008), sweet basil (Borowski & Blamowski 2009), common duckweed (Kilic *et al.,* 2010), ginger (Singh *et al*., 2011), maize (Ertani *et al.*, 2013), sunflower (Aziz *et al.*, 2013), canola (Zulfiqar & Shahbaz 2013) and wheat (Perveen *et al.*, 2014).

Therefore, foliar application of such growth regulators has emerged as "Magic signaling chemicals or novel growth regulators" that would enhance the maize growth at an unprecedented rate and thereby facilitate in eliminating and circumventing various phenotypic as well as genotypic barriers so that plants can withstand under abiotic stress conditions. Thus, based on the previous exploration, present attempt was undertaken to assess and explore whether TRIA could accelerates the physio-biochemical growth and augment the productivity of maize hybrid *vis-à-vis* it could improve drought tolerance in maize plants grown under Red and Lateritic soil of Bankura district in West Bengal which is inherently drought-prone area.

MATERIALS AND METHODS

In order to assess the physio-morphological and biochemical growth response of maize under different levels of TRIA, a field experiment was designed and planted during summer season of 2020 and 2021 at College of Agriculture, BCKV (Bankura Extd Campus), Chhatna, West Bengal. Maize hybrid *viz*., Pioneer (P-3355) was grown under moderate drought stress and non-stress conditions in order to induce the level of drought tolerance in maize.

Seeds (TL class) of the maize hybrid were sown in plastic cups filled with soil mixed with vermicompost (200 g in each). Seedlings of 25 days old were transplanted into the main plots with a size of 4m × 2m and follow the spacing of 60cm × 30cm. The experiment was designed (CRD) with three replications. Foliar application of three TRIA doses (Miraculan 0.5% EC) with 1500ppm, 2000ppm and 2500ppm was performed at 30 DAS, 60 DAS (initiation of tasseling stage) and 90 DAS. Moderate drought stress was given to the plants 10 days earlier than foliar treatments of TRIA at different doses. For data recording, five plants have selected with aluminum tags from each replication.

Extraction and Estimation of Chlorophyll contents: 300mg leaf sample was used to crush into fine pulp in mortar pestle by adding 10ml of 80% acetone. The suspension was taken in a centrifuge tube and centrifuged for 10 minutes at 5000rpm. The supernatant was taken in a conical flask and then 10ml of 80% acetone was added to the residues that obtained after the collection of supernatant and the residues mixed with acetone was stirred by glass rod. This suspension was again need to be centrifuged at 5000rpm for 5 minutes. The supernatant thus obtained have to be mixed with the earlier supernatant. The volume of the combined extract was made up to 25ml with the addition of 80% acetone. The absorbance was taken at 645nm and 663nm wavelengths from the combined supernatant in a spectrophotometer against the solvent (80% acetone) as blank.

Total chlorophyll was estimated from the absorbance values at 645nm (A645) and 633nm (A663) according to the Arnon (1949) as follows:

Total Chlorophyll (mg/g of fresh leaf sample) = $[(20.2 \times A645) + (8.02 \times A663)] \times V/1000W$

Whereas, V=Volume of the extract (ml); W= Fresh weight of the leaf sample (g); A= Absorbance

Relative Water Content (RWC): Relative water status of the leaf sample was estimated from five randomly selected plants from each plot at 30, 60 and 90 DAS. The leaf fresh sample was weighted and then soaked in distilled water for 8 hrs. After soaking, blotting was done for surface drying and then turgid weight (TW) was measured at water saturated condition. After that, the leaf samples were oven dried at 80°C for 24 h till to obtain their constant dry weight (DW). By following the formula suggested by Gonzalez and Gonzalez 2001 RWC was calculated:

RWC (%) = $(FW-DW) / (TW-DW) \times 100$

Whereas, FW is the sample fresh weight, TW is the sample turgid weight and DW is the sample dry weight.

Membrane Stability Index (MSI): Electrical conductivity was measured from 100 mg of leaf discs with uniform diameter and taken in 10 ml double distilled water in two sets of test tubes. One set of test tube was taken at 40°C in a boiling water bath for 30 min and measured (C1) electrical conductivity of the sample using a conductivity meter.

The second set of test tube was incubated at 100°C in the boiling water bath for 15 min and recorded electrical conductivity (C2). MSI was measured following the method suggested by Premchandra *et al.* (1990) which further modified by Sairam (1994):

$$MSI = [1-C1 /C2] \times 100$$

RESULTS AND DISCUSSION

TRIA-mediated growth attributes in maize: The beneficial effect of TRIA regulated growth responses was measured in terms of plant height, number of leaves from 90 DAS old plants, number of green leaves at harvest, flag leaf area, ear height and tassel internodes length in maize hybrid, Pioneer (P-3355). On an average observation, the relationship between various growth parameters like plant height, number of leaves during 90 DAS, number of green leaves at harvest was found significant and positive due to Tricontanol treatments at three concentrations. Plant height were measured at 90DAS and observed that there was 20.40% increase when maximum dose of TRIA (2500ppm) applied (Table 1). Number of leaves at 90DAS as well as number of green leaves at harvest also has the increasing trend with the intensity of concentration. These results has confirmed with the previous findings of Kumaravelu *et al.* (2000); Naeem *et al.* (2012). According to their findings, TRIA regulate plant growth through cell division, elongation and cell enlargement. There was an increasing trend of growth enhancement with the increase in TRIA concentration both under non-stress and stressed conditions.

Under moderate drought stress created by allowing irrigation at 60% field capacity causes a significant reduction (more or less) in all the growth parameters (Table 2). However, such reduction may be able to be mitigated a little bit when tricontanol applied as foliar during different stages of growth. But full recovery of drought stress not has been possible by such foliar application.

Regarding other growth parameters like flag leaf area, ear height and tassel internodes length, there was a significant reduction in such growth parameters while grown under moderate stress. Such reduction imposed by drought can be overcome by tricontanol application (Table 2).

Table 1: Influence of TRIA on some physio-morphological growth parameters in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under normal watering (at 100% of the field capacity) condition.

Treatments	Plant height at 90 DAS (cm)	No. of leaves at 90 DAS	No. of green leaves at harvest	Flag leaf area (sq.cm)	Ear height (cm)	Tassel internodes length (cm)
T_0: Control	237.34	14.82	2.66	300.23	66.50	12.51
T_1: TRIA @ 1500ppm	255.40	14.96	3.29	316.54	67.13	13.20
T_2: TRIA@ 2000ppm	268.32	15.32	3.50	333.28	70.54	13.78
T_3: TRIA @2500ppm	285.75	15.67	3.78	350.11	72.0	13.98
S.Em±	1.88	0.123	0.11	4.70	0.49	0.108
CD (P=0.05)	5.34	0.359	0.32	NS	NS	NS

Table 2: Influence of TRIA on some physio-morphological growth parameters in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under moderate drought stress (at 60% of the field capacity) condition.

Treatments	Plant height at 90 DAS (cm)	No. of leaves at 90 DAS	No. of green leaves at harvest	Flag leaf area (sq.cm)	Ear height (cm)	Tassel internodes length (cm)
T_0: Control	225.11	10.66	1.87	256.41	59.07	10.08
T_1: TRIA @ 1500ppm	233.0	11.00	2.36	278.03	60.35	10.39
T_2: TRIA@ 2000ppm	242.57	12.47	2.59	298.54	65.07	11.14
T_3: TRIA @ 2500ppm	260.09	13.21	2.89	312.76	68.02	11.23
S.Em±	1.72	0.096	0.08	4.14	0.45	0.086
CD (P=0.05)	4.90	0.280	0.235	NS	NS	NS

TRIA-mediated yield attributes in maize: Triacontanol plays an important positive role in regulating some yield contributing characteristics *viz.*, number of cobs per plot, cob dimension, number of rows per cob, number of seeds per row of cob and per cob under non-stress (Table 3) and moderate stress (Table 4) conditions. Maximum cob length (20.50cm) was observed at T_3 that contribute 22.02% increase that untreated control (16.80cm) but cob length reduced into 13.65cm when grown under moderate drought. Such reduction in cob length may be mitigated by foliar application of TRIA whereas 24.91% enhance of cob length (17.05cm) was observed at T_3.

Table 3: Influence of TRIA on some growth and yield attributing parameters in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under normal watering (at 100% of the field capacity) condition.

Treatments	Total no. of cobs/ plot	Cob length (cm)	Cob fresh weight (g)	No. of rows/ cob	No of seeds/ row of cob	Total no. of seeds/ cob	Seed weight/cob (g)	Test weight (g)	Seed yield (kgha^{-1})
T_0: Control	50	16.80	310.88	14	32.51	455.14	145.63	333.60	2625.14
T_1: TRIA @ 1500ppm	54	17.70	315.24	14	33.42	467.88	156.12	348.0	2678.65
T_2: TRIA @ 2000ppm	57	18.90	326.46	15	34.50	517.50	166.03	358.80	2711.30
T_3: TRIA @ 2500ppm	60	20.50	335.32	16	35.33	562.28	174.78	369.50	2790.25
S. Em ±	0.55	0.27	7.34	0.12	0.503	7.428	3.67	0.23	48.68
CD(P=0.05)	2.08	0.95	20.89	0.35	1.429	21.095	10.43	0.88	138.56

Regarding the number of seeds per cob, it was also observed an enhancing rate from 455.14 to 562.28 and reduced into 415.70 when grown under stress. However, reduced number of cobs (415.70) could be increased into 456.59 (T_2) and 488.49 (T_3). Parameters like cobs/plot and number of rows per cob also showed more or less similar trends of results.

Yield contributing characters like seed weight per cob, test weight and seed yield per hectare of land also observed to evaluate the beneficial effect of TRIA. Test weight increases from 333.60g to 369.50g under non-stress and decreases up to 306.58g under stress but it may enhance into 345.95g under TRIA treatment at T_3. However, the full recovery of the stress could not be possible at par under non-stress at T_3 (369.50g). Seed yield increases from 2625.14 kgha^{-1} to 2790.25 kgha^{-1} under normal watering (Table 3) but there was a non-significant results observed under stress conditions (Table 4). TRIA treatment improves several yield contributing parameters that might have due to betterment in the biosynthesis of nucleic acids, proteins, enhanced photosynthetic activity leads to higher source-sink ratio and increased cell division, better root growth and development. Similar kind of results was conformed as suggested the findings of Harris *et al.* (2007); Giovacchino *et al.* (2001); Shafinazir *et al.* (2000).

Table 4: Influence of TRIA on some growth and yield attributing parameters in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under moderate drought stress (at 60% of the field capacity) condition.

Treatments	Total no. of cobs/ plot	Cob length (cm)	Cob fresh weight (g)	No. of rows/ cob	No of seeds/ row of cob	Total no. of seeds/ cob	Seed weight/cob (g)	Test weight (g)	Seed yield (kgha^{-1})
T_0: Control	43	13.65	300.07	11	27.03	415.70	122.40	306.58	2200.56
T_1: TRIA @ 1500ppm	48	14.81	309.87	12	29.78	427.15	136.61	317.50	2365.00
T_2: TRIA @ 2000ppm	50	15.89	315.09	12	30.99	456.59	140.10	329.48	2387.25
T_3: TRIA @ 2500ppm	55	17.05	323.98	14	32.58	488.49	156.39	345.95	2469.05
S. Em ±	0.46	0.22	7.11	0.10	0.45	6.63	3.17	0.16	42.44
CD(P=0.05)	1.73	0.79	NS	0.29	1.27	NS	9.02	0.62	NS

TRIA-mediated physio-biochemical attributes in maize: Leaf chlorophyll was measured as it is the most important independent factor affecting spectral reflectance. Table 5 represents the chlorophyll contents of the leaves measured at 30, 60 and 90DAS and generally chlorophyll contents attained it maximum level at 60DAS and then reduces with the ages of the leaves both under normal and stress conditions. Chlorophyll content under drought is always dependent upon the intensity and duration of the stress, stage of the crop and extent of genetic tolerance to drought (Kabiri *et al*., 2014). Total chlorophyll content was measured as 1.09 under non-stress and reduces into 0.88 under stress during 60DAS. The total chlorophyll contents increased by about 34.86% and 44.05% respectively in TRIA-treated plants@2500ppm under non-stress and moderate stressed conditions during 60DAS. Treatment with TRIA played a significant positive effect on the repair of chlorophyll content in leaves in all the growth stages. The content of chlorophyll when treated with 2000 and 2500ppm noticed an increasing trend for all the duration of the growth. In rice seedlings, foliar application of TRIA exhibit better results on chlorophyll content (Muthuchelian *et al.*, 1997; Kumaravelu *et al.*, 2000), in maize and wheat (Ries 1991). TRIA treatment increases the chlorophyll content by increasing the number and size of the chloroplast (Ivanov and Angelov 1997; Chen *et al.*, 2003; Muthuchelian *et al.*, 2003).

Table 5: Influence of TRIA on total chlorophyll contents in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under normal watering (at 100% of the field capacity) and moderate drought stress (at 60% of the field capacity) conditions.

	Total chlorophyll contents (mg g^{-1} of fresh weight) under non-stress condition			Total chlorophyll contents (mg g^{-1} of fresh weight) under water stress condition		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
T_0: Control	0.68	1.09	0.94	0.59	0.88	0.75
T_1: TRIA @ 1500ppm	0.74	1.16	1.07	0.63	1.04	0.91
T_2: TRIA @ 2000ppm	1.02	1.33	1.19	0.89	1.11	0.99
T_3: TRIA @ 2500ppm	1.18	1.47	1.26	1.03	1.25	1.08
S. Em ±	0.047	0.066	0.058	0.045	0.060	0.053
CD(P=0.05)	0.143	0.199	0.176	0.137	0.187	0.163

Relative Water Content (which was previously known as **relative turgidity**) is a reproducible and momentous indicator of plant grown under drought. Table 6 represents the beneficial effect of TRIA on Relative Water Content and Membrane Stability Index of the maize. Both the RWC and MSI were maximum during 60DAS but with the intensity of drought as well as growth duration causes a reduction of both the parameters. Such reduction of water content could be improved by application at different doses and better results were obtained with the increasing of TRIA concentration. During 60DAS, 87.45% of RWC was measured under non-stress whereas stress caused a reduction into 80.42% but RWC improved a little bit by 1.26% and 0.88% under non-stress and stressed conditions respectively. MSI also reduced from 80.58% (no-stress) to 70.58% (stress) during 60DAS that could be enhanced by 0.99% and 1.62% when treated with TRIA @2500ppm respectively. From the results, it might be concluded that RWC and MSI can be improved by foliar application of TRIA even under drought condition. Ries and Wert (1982) observed that some physiological activities have been enhanced by escalating the purity percentage of TRIA up to 99.7% in maize and rice seedlings.

Table 6: Influence of TRIA on Relative Water Content and Membrane Stability Index in maize (*Zea mays* L.) hybrid treated with Triacontanol (TRIA) under normal watering (at 100% of the field capacity) and moderate drought stress (at 60% of the field capacity) conditions.

Treatments	RWC (%) under non-stress			MSI (%) under non-stress			RWC (%) under water stress			MSI (%) under water stress		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_0: Control	85.33	87.45	86.27	80.12	80.58	79.69	80.13	80.42	80.21	70.0	70.18	69.77
T_1: TRIA @ 1500ppm	85.65	87.62	87.11	80.69	81.0	79.84	80.78	80.79	80.65	70.25	70.68	69.80
T_2: TRIA @ 2000ppm	86.30	87.81	87.75	80.99	81.13	81.06	80.99	80.99	80.65	70.39	71.30	70.09
T_3: TRIA @ 2500ppm	87.19	88.53	88.60	81.14	81.38	80.36	81.68	81.13	81.0	70.64	71.32	70.96
S. Em ±	1.01	1.04	1.10	0.95	0.96	0.94	0.95	0.95	0.95	0.83	0.84	0.82
CD(P=0.05)	3.82	3.90	3.88	3.58	3.60	3.56	3.59	3.58	3.57	3.12	3.11	3.11

TRIA-modulated drought stress in maize: In the present study, it has been observed that drought stress implies a negative effect on plant growth, yield attributing characters and also some physio-biochemical parameters. However, such reducing effect of stress depends on the intensity and duration of stress, stages of the plant and genetic behavior as well as tolerance of the plant species etc. It has been found from the previous literature that plant can overcome the drought stress when exogenously applied by TRIA due to their signalling relationship with abiotic stress. Foliar application of TRIA helps to adjust osmotically towards cellular environments through the accumulation of several osmolyte like proline, glycine betaine etc. Under drought, foliar application of TRIA at different levels decreases the H_2O_2 and MDA contents due to their antioxidant activities (Ramanarayan *et al.*, 2000) in *Spinaceae oleracea* L. It reduces oxidative damages in several crop species like wheat (Perveen *et al.*, 2014), and *Arachis hypogaea* L. (Verma *et al.*, 2011) under stress.

In addition, TRIA act as a signaling molecule that could enhance its activity by integrating with other growth regulators like gibberellins and cytokinins (Verma *et al.*, 2009; Aftab *et al.*, 2010) and also increase other signaling molecule like Ca^{2+} (Perveen *et al.*, 2014). TRIA can reverse the detrimental effect of drought and improves the drought tolerance in pine seedlings (Rajasekaran and Blake 1999) and inhibits lipid peroxidation (Ramanarayan *et al.*, 2000). TRIA helps in increasing soluble protein under stress and causes a cascade of metabolic events that ultimately results in noteworthy increases in growth and dry matter production in plants under abiotic stress (Ries and Wert 1992). TRIA mediated growth regulation under stress possibly due to an increase in leaf area, enhanced photosynthesis, increase in the activities of RUBISCO and NR, increased CO_2 fixation, enzymatic activities, biosynthesis of chlorophyll and carotenoids, starch and sugars etc as exposed by Muthuchelian *et al.* (2003) in seedlings of *Erythrina varietaga* under stress.

CONCLUSIONS

Based on the overall experiment conducted, results indicated that different growth parameters as well as yield attributing characters, and physio-biochemical growth regulation mediated by exogenous TRIA application in leaves of maize were significantly and positively correlated with each other. Meanwhile, the positive and highly significant relationship between various attributes was also noticed in case of foliar spray of TRIA at different levels both under normal irrigation and moderate stress conditions.

Treatment by TRIA at T_3 (2500ppm) was better whereas T_1 (1500ppm) followed by T_2 (2000ppm) also played little bit beneficial role in growth modulation in maize and thus induce drought tolerance. Such growth regulator at various levels may be attributed to decrease chlorophyll degradation and increased chlorophyll biosynthesis; increase membrane stability and relative water content and stimulates the growth of the plant by decreasing CO_2 inhibition that in turn increases CO_2 assimilation and enhance photosynthesis. On the whole, it can be concluded that various levels of TRIA played a significant and positive relationship on the growth regulation of maize under moisture stress condition.

FUTURE SCOPE

As a novel plant growth promoter TRIA plays pivotal role in the up-regulation of many physio-morphological and biochemical processes in crops like maize. It helps in boosting up the growth and yield enhancement of several crops both under normal and abiotic stress conditions. That is why the exogenous application of TRIA can successfully be employed in upcoming future for such crop growth and productivity recommended to some other field crops, trees, medicinal and aromatic plants etc. But for improving the possible growth regulation by TRIA, further investigations are therefore essential to elucidate physio-morphological and biochemical growth responses under normal and abiotic stress conditions.

Traditionally, some Plant Growth Regulators (PGRs) that are primarily involved in the plant growth regulation uses to boost up the drop growth and productivity which is normally more expensive. In very recent times, in addition to five classical phytohormone (auxins, cytokinins, gibberellins, abscisic acid and ethylene), some Novel Plant Growth Regulators (NPGRs) are accountable for growth regulation at the cellular, molecular, morphological as well as physio-biochemical level. At present, there is an urgent need for composite plant growth regulation to enhance agricultural production and productivity in a sustainable manner and eco- friendly approach. For attaining such goals, low-priced PGRs like TRIA may be advantageous which fulfills the extraordinary needs and easily be afforded. In recent future TRIA may be explored in combination with other reasonably low-priced PGRs to enhance the performance of maize growth to a large and desirable extent.

It is utmost required to studies further elicitation of TRIA-mediated growth and metabolism in forthcoming future where a combined approaches or application of TRIA with other PGRs would enable to explore the crop more economically feasible at a greater extent.

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Conflict of Interest. None.

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