Triacontanol : A Promising Plant Growth Regulator

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Introduction

Demand for agricultural crops continues to rise as a result of rising population and damage to fertile cropland. Plant growth regulators (PGRs) are commonly used in crop production to maximize plant growth and productivity by increasing fruit set, fruit number, and weight. It is involved in flowering, fruit set, ripening, and physiochemical changes that occur during storage. Plant growth inhibitors are used to reduce the length of a plant's shoots without altering developmental patterns or causing phototoxicity. In fact, the use of growth regulators had improved the production of vegetables in terms of growth and quality, which sparked interest among scientists and farmers for the commercial application of growth regulators. This was accomplished not only by limiting cell elongation, but also by slowing the rate of cell division and physiologically regulating plant height.

Triacontanol (TRIA) is a natural novel plant growth regulator found in plant cuticular waxes and bee wax. It is a straight chain 30 carbon fatty alcohol i.e., primary alcohol is an endogenous hormone which is active at very low concentration on the cell membranes. The chemical name is triacontanol-1 or n-triacontanol, referred to as triacontanol or TA or TRIA, also known as benzyl alcohol. Triacontanol (TA) is a non-toxic, pollution-free, low - cost, high - efficiency, broad - spectrum plant growth regulator that plays an important role in plant growth and development. TRAI can significantly increase the amount of chlorophyll in leaves, improving photosynthesis and also overcome various stress in plants.

Triacontanol (TRIA), an endogenous plant growth regulator, promotes a variety of metabolic activities in plants, resulting in improved growth and development. TRIA also plays an important role in reducing stress-induced changes in crop plants by modulating the activation of stress tolerance mechanisms. The role of exogenously applied TRIA in plant morpho-physiology and biochemistry, for example, in terms of growth, photosynthesis, enzymatic activity, biofuel synthesis, yield and quality under normal and stressful conditions, is discussed in this paper.

The TRAI and GA_3 can stimulate the formation of a bud, flowers and plant branching, increase photosynthesis and plant metabolism, stimulate cell growth, build a healthy root system, thicken plant foliage and flowers make stem and root stronger and help new cuttings grow a fast root, all of which can increase plant yields and quality.

Mode of Tria Action

Many investigators have explored the effects of TRIA on several basic metabolic processes including photosynthesis, nutrient uptake, and enzyme activities. Several efforts have been made to elucidate the mechanism of TRIA action (Ries *et al*. 1993). Assumption of a cascade effect led to the identification of 9-ß-L (+)-adenosine as a second messenger of TRIA (Ries *et al*. 1993). TRIA rapidly elicits the second messenger (TRIM) in rice (Oryza sativa L.), which at nanomolar concentrations causes the plants to respond in a manner similar to TRIA (Ries 1991). TRIM has been identified as 9-ß-l (+)-adenosine (9H-purin-6-amine, 9-ß-L-ribofuranosyl). TRIA enhanced the formation or release of L(+)-adenosine in the root tissue of rice seedlings within one min of TRIA application to the shoots, which might have elucidated the first step in the mode of TRIA action. It is already reported that TRIA rapidly increases the ratio of l (+)-adenosine to d(–)-adenosine, probably at the tonoplast (Ries 1991). There remains the problem of how TRIA elicits l(+)-adenosine and what is the source of l(+)-adenosine in plants. Based on known metabolic processes, de novo synthesis of l(+)-adenosine is unlikely, because of the rapidity of the response. The most probable source of adenosine is AMP derived from ADP and ATP (Olsson and Pearson 1990). In TRIA treated plants, the nonracemic L(–)-adenosine (–11%) is released to affect plant processes (Ries 1993). Salt stress causes decrease in plant growth and productivity by disrupting physiological processes, especially photosynthesis. The accumulation of intracellular sodium ions at salt stress changes the ratio of K : Na, which seems to affect the bioenergetic processes of photosynthesis. Iyengar and Reddy (1996) noted that decreases in photosynthetic rate in saline condition resulted from a number of factors including:

Response of Plants to TRIA

a. Growth attributes : According to several research, TRIA applied to the root medium or the leaves improved the growth and productivity of vegetables and cereal crops. (Ries *et al.* 1993). TRIA has been proven to propel the growth and/or yield of a broad array of annual vegetables, agronomic and horticultural crops, and forest species. The increase in yield is due to the rapid increase in the net assimilation rate as observed in tomato after TRIA spray. In greenhouse studies, foliar applications of 1.0-100 mg L-1 of L(+)-adenosine increased the growth of tomato (*Lycopersicon esculentum* Mill.), maize (*Zea mays L*.), cucumber (*Cucumis sativus L*.), and carrot (*Daucus carota L.*) (Ries *et al.* 1990). Furthermore, Eriksen *et al.* (1982) observed a TRIA-mediated increase in the dry weight of tomato seedlings in controlled environment research; however, no similar dry weight increase was detected in maize seedlings. When seeds were treated with TRIA, it had no effect on seed germination or early growth in several species, but it did have a substantial effect on improving the rate of cotton germination (*Gossypium hirsutum*).TRIA foliar spray boosted the dry weight of rice seedlings in nutritional medium, as well as corn, barley, and tomato plants (Ries *et al.* 1993).TRIA's growth-promoting effects on a

Triacontanol Mode of Action

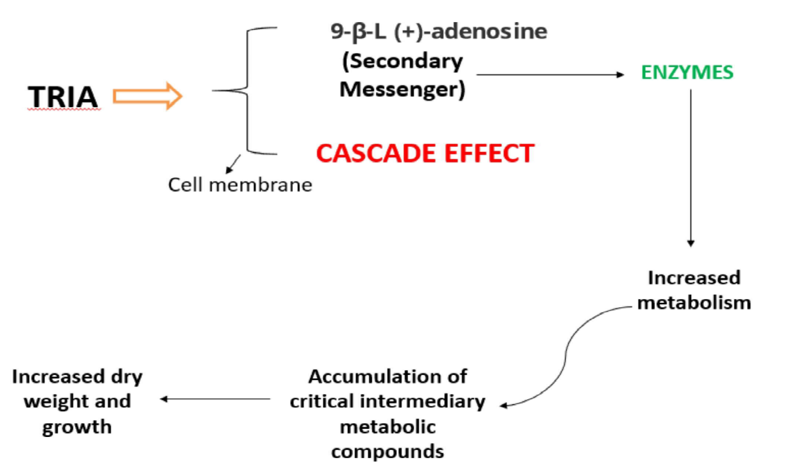

Figure 2. Mode of action of triacontanol (TRIA)[Source-Naeem *et al.* 2012]

variety of plant attributes, including plant height, fresh and dry weights, leaf area, and root nodulation, have been studied by a number of researchers in a variety of medicinal crops (Chaudhary *et al.* 2006). TRIA alone and in combination with potassium increased tomato plant height, fresh and dried weights, and leaf area per leaf (Khan *et al*. 2009).

b. Physiological and biochemical attributes : When applied exogenously, TRIA has been found to regulate a variety of physiological and biochemical processes directly or indirectly. (Naeem *et al.* 2012). The initial step toward understanding TRIA function was isolating and profiling TRIA-regulated genes, which provided clues to the biochemical pathways and physiological processes that control, as well as expose the components involved in TRIA signalling (Chen *et al*.2002). Photosynthesis was linked to an increased number of TRIA sensitive genes. TRIA improved the state of photosystems and increased the level and activity of ribulose-1,5-bisphosphate carboxylase oxygenase (RuBisCO) (Chen *et al.* 2002). Photosynthesis has been identified as a key plant response to TRIA, with improved photosynthesis and greater photosynthate accumulation being ascribed to increased plant growth and dryweight. TRIA also enhanced the activity of malate dehydrogenase, a crucial respiratory enzyme. In a study, Borowski *et al.* (2009) revealed that the maximum efficiencyof PS-II in the dark (Fv/Fm) was clearly increased by the applied TRIA and the efficiencyof excitation-capture by PS-II reaction centers were even much increased. In fact, a number of studies have demonstrated an increased rate of CO_2 fixation and photosynthesis in a variety of plant species as a result of TRIA application in nanomolar concentrations. Similarly, TRIA alone or in combination with gibberellic acid significantly increased the net photosynthetic rate, stomatal conductance and internal CO_2 concentration in Artemisia annua. Moreover, also found the significant effect of TRIA on photosynthetic parameters regarding hyacinth bean (*Lablab Purpureus L.*), coffee senna (*Senna occidentalis L.*), and Japanese mint (*Mentha arvensis L*). In addition, the contents of photosynthetic pigments were significantly influenced by exogenous application of TRIA. The content of the pigments in TRIA-treated leaves could presumably be attributed to the increase in the number and size of chloroplasts as revealed by Chen *et al*. (2003). As a result of foliar sprayof TRIA at early vegetative stages, Naeem *et al*. (2012) reported an increase in the nodule-nitrogen and leghemoglobin contents of hyacinth bean at 60 days after sowing (DAS) followed by that at 90 DAS. The TRIA alone or in combination with gibberellic acid significantly enhanced the activities of NR and CA in artemisia (Aftab *et al*. 2010). Sharma *et al.* (2002) suggested that a higher content of leaf-nutrients in TRIA treated plants could be attributed to the higher metabolic activity and increased drymatter production that might result in enhanced water and nutrient uptake from soil subsequently.

c. Yield and quality attributes : TRIA has been used to increase the productivity of food crops and vegetables in the past few decades with great success. TRIA exhibited a substantial increase in production on various crops, including dry beans, sweet corn and cucumbers, in the early studies. Improvement in yields of several important food crops have been recorded by several researchers as a result of TRIA application. Borowski *et al.* (2000) reported significant increase in tomato yield as result of TRIA application at 0.3 and 3.0 mg L-1. Another study found that when TRIA was sprayed as foliar sprays, there was a significant increase in total and per-plant tomato yield; but, when TRIA was added to the growth medium, there was only a transitory increase in yield and number of fruits. When the TRIA was used in combination with GA3 on the coriander crop, the maximum numbers of umbels, fruits per umbel, 100 seed weight, and seed yield were reported (Idrees *et al*. 2010). Foliar application of TRIA, at a concentration of 0.5 mg , significantly promoted the contents of saccharides, starch, soluble proteins, amino acids and phenols in green gram (Kumaravelu *et al*. 2000). TRIA application also improved the contents of soluble protein, starch, sugars, and free amino acids in the leaves of Oryza sativa and Zea mays. Moreover, Naeem *et al*. (2010) reported a significant positive effect of TRIA on the seed-content of protein and carbohydrate in hyacinth bean. Similarly, carbohydrate and protein contents in turmeric (*Curcuma longa L*.) and ginger (*Zingiber officinale Rosc*.) were significantlyimproved bythe foliar sprayof TRIA (Singh *et al*. 2011).

Conclusion

TRIA administered at nanomolar concentrations promotes plant growth and physiological activity in a variety of plant species, according to compelling data. TRIA has been shown to boost the growth, yield and quality of a variety of crops, including vegetables, horticultural crops and medicinal and aromatic plants, when applied foliarly. Increased production of secondary plant products, such as essential oil and active components of medicinal and aromatic plants, is also facilitated by TRIA-mediated increases in dry matter. However, more research is needed to determine the significance of TRIA in the regulation of plant development and metabolism in terms of gene expression regulation.

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