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RESEARCH ARTICLE

Effect of plant growth regulators for yield enhancement in finger millet under drought stress

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Abstract

Finger millet (Ragi) is considered as wonder millet because of its high nutritive and therapeutic values. Drought is a major abiotic stress which limits the crop production and yield potential of finger millet. Considering the yield losses faced by the farmers during drought condition, foliar application of plant growth regulators (PGRs) is widely used to improve the physiological response that might lead to rapid changes in phenotype of the plant and enhancing the production of crops. Finger millet is less efficient in partitioning of assimilates and has low actual yield potential even as a C4 crop. To address these issues, experiments were conducted for improving the partitioning efficiency and yield. Hence, an experiment was conducted to mitigate the drought in finger millet through PGRs. The stress was imposed during flowering stage in the finger millet variety CO15 where different kinds of PGRs viz., Brassinosteroid, Salicylic acid and Chlormequat chloride were used in this experiment. After imposing the treatments, physiological, biochemical and yield traits were recorded. Foliar spray of 0.3 ppm brassinosteroid and 100 ppm salicylic acid exhibited superior performance for improving the osmotic potential, reduces the membrane lipid damage, better chlorophyll pigments, nitrate reductase activity and improved antioxidant system which leads to mitigate the negative impacts of drought in finger millet.

Keywords

finger millet; foliar spray; mitigation and yield; physiological traits

Introduction

Millets are one of the important major food sources in arid and semiarid regions of the world because of high quantity of proteins, carbohydrates, fatty acids, minerals, vitamins, dietary fibre and polyphenols (1, 2). Among the millets, finger millet is also known as ragi (*Eleusine coracana* L. belongs to Graminae/ Poaceae family and the inflorescence is panicle, which is in the whorl of 2-11 digitate, straight or slightly curved spikes) which is called as "Nutritious millet" as it has fair number of proteins, rich in minerals, calcium, vitamins and fibre content (2). This crop belongs to a broad class of small grains known as minor millets, which are grown in a variety of challenging conditions, primarily in agro ecosystems that are dry, semi-arid, to sub-humid and vulnerable to drought. India is the major finger millet producing country in Asia (26,13,000 t), followed by Nepal (1,22,000 t), China (79,000 t) and Afghanistan (38,000 t) (3). During 2023-2024, 40.34 lakh tons of ragi were produced in India, with 2.82 lakh tonnes produced in Tamil Nadu (4). Drought is one of the biggest factors affecting crop productivity by affecting many features of plant growth and physiological processes (5). This could lead to a decline in overall crop productions. The world's largest producer of soybeans and maize, the United States, experienced its worst drought in more than half a century in 2012 (6). Every three years, India has had severe and frequent droughts (7) and in the upcoming decades, especially between 2020 and 2050 (8), it is expected that both the frequency and intensity of these events will increase. Because of this, the state of Tamil Nadu noticed one of the worst droughts in 140 years in 2016-17. With an 82% rainfall deficit, one of the lowest in India, the government was forced to proclaim a drought, which caused significant disruptions across the state (9).

Finger millet yield is affected by water deficit and the reduction in yield was upto 50-80% due to the decrease in leaf area, radiation use efficiency, dry matter accumulation, seed weight under drought condition (10). Application of Plant growth regulators (PGRs) is one of the strategies to improve partitioning efficiency of finger millet under drought condition. Plant growth regulators are thought to be small signalling molecules that serve a variety of purposes for plants. Brassinosteroids (BRs) are unique phytohormones exhibited much gas exchange in maize (11) and increased the yield of pearl millet (12). In this light of view, the present investigation was focused to mitigate the drought stress through application of PGRs.

Materials and Methods

Experimental site and imposition of stress

The experiment was conducted at Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. Pot mixture was prepared by using red soil, sand and vermicompost in the ratio of 3:1:1 and 12 kg of soil mixture was filled in the pots. The seeds were directly sown in the pot. After the establishment of seedlings, thinning was done to maintain two seedlings per pot uniformly across the replication. The package of practices was carried out as per the Crop Production Guide of Tamil Nadu Agricultural University, Coimbatore. The CO15 variety was used in the experiment and the treatments were as follows: T1: Absolute control (irrigated); T2: drought control; T3: Salicylic acid (100 ppm); T4: Brassinosteroid (0.3 ppm); T5: Chlormequat chloride (200 ppm) and the experiment were set up with three replications, using a factorial completely randomized design (FCRD). The concentration of the PGRs mentioned in this experiment is already used in diverse crop plants and hence, it was used directly without doing any standardization. The treatments were applied to the foliage during the stress, induced at flowering stage. Water was not given for seven days (from day 62 to day 68) and foliar spray was applied on 65th day. Using a moisture meter (Data Devices Theta Probe), the moisture content of the soil was measured every day. Data on soil moisture were recorded until the final rewatering, at which point the plant growth regulators were sprayed and the reduction in soil moisture reached around 50% field capacity. The observations were made 1, 2 and 3 days after foliar spray (DAF) of PGRs.

Measurements on physiological, biochemical and yield attributes

Total chlorophyll content was determined by DMSO method and expressed as mg g^{-1} of fresh weight (13). The osmotic potential was measured using a vapour pressure osmometer (Vapour Model 5520 Wescor Inc., Logan, UT, USA) and calculated by using the standard method (14). Nitrate reductase acivity (NRase) in leaves was estimated as per the standard protocol and expressed as µg of NO_2 g^{-1} h^{-1} fresh weight (15). The leaf proline content was measured and reported as mg g^{-1} of fresh weight (16). By measuring the MDA equivalents with 2-thiobarbituric acid (TBA), the lipid peroxidation level was calculated and represented in µmol g^{-1} of fresh weight (17). Superoxide dismutase (SOD) activity was determined by using nitrobluetetrazolium (NBT) salt and expressed in enzyme units mg^{-1}protein (18). At harvest stage, the yield attributes *viz*., number of productive tillers, ear head length, ear head weight and grain yield were recorded in all the treatments and replications.

Statistical Analysis

Factorial Completely Randomized Design (FCRD) analysis was used in this study and mean, standard error, critical difference and ANOVA were computed by using Excel and SPSS 16.0software packages. MS Excel was used to create the relevant graphs along with the corresponding standard deviation. Finally, the data were tested at five per cent (*) and one per cent level (**) of significance and where (NS) denotes non-significant.

Results and Discussion

Foliar application of PGRs on physiological, biochemical and yield traits of finger millet were investigated under drought condition. Drought stress is the major factor limiting plant growth and productivity. In addition to strengthening the plant's defence mechanism against dry conditions, plant growth regulators are crucial to the physiological functions of plants (19). In comparison to the control under drought conditions, the kind of drought stress had a significant impact on plant treated with foliar application of PGRs.

Total chlorophyll content indicates the pigment concentration of chlorophyll which absorbs and transfers the light energy from the atmosphere to the micro molecular compounds in chloroplast for the fixation of atmospheric CO_2 for photosynthesis. The drought persuaded alterations in chlorophyll content due to impaired biosynthesis or accelerated pigment degradation. Various studies have shown that the PGRs increased the chlorophyll content under drought conditions (12). The notable observation of present research is that foliar spray of BR (0.3 ppm) followed by SA (100 ppm) increased the total chlorophyll content (Fig. 1). Brassinosteroid activates the enzymes for the synthesis of pigments, cell division and protecting chlorophyll from degradation by chlorophyllase enzyme. The report revealed that highest chlorophyll content was recorded in rice (20), pearl millet (12) and in wheat (21) due to application of BRs. Similarly, application of salicylic acid increased the chlorophyll content in wheat under drought condition (22). This is in confirmation with the present experiment where foliar spray of BR and SA significantly influenced the chlorophyll content. Similar findings were previously reported which stated that application of BR increased the chlorophyll content in aroma rice (23).

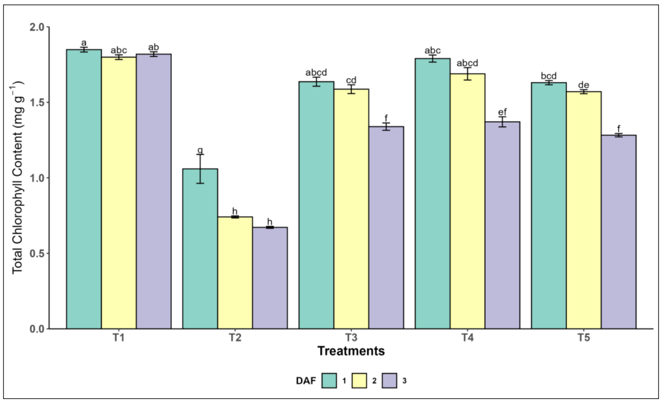

Fig. 1. Effect of PGRs on total chlorophyll content (mg/g) in finger millet under flowering stage stress condition (DAF - Days After Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

Osmotic potential is one of the strategies for a plant to tolerate osmotic and water deficit stresses (19). Foliar application of brassinosteroid has tolerance mechanism as decline in leaf osmotic potential, to sustain their water status in finger millet under drought condition (Fig. 2). Lower osmotic potential maintains turgor pressure which helps to open the stomata and improved the photosynthesis under drought condition (24, 25). Furthermore, BRs' ability to strengthen plants' antioxidant enzyme systems is frequently utilized to help them become more resilient to a variety of abiotic stress (26, 27)

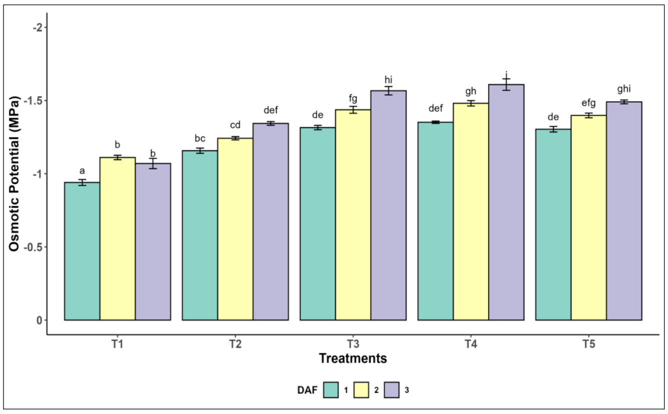

Fig. 2. Effect of PGRs on osmotic potential in finger millet under flowering stage stress condition (DAF - Days After Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

Nitrate reductase (NRase) is an enzyme that is crucial for nitrogen uptake and protein synthesis in plant cells that are extremely vulnerable to drought stress since the plant metabolism and physiological function depends on this enzyme activity (28). Foliar spraying salicylic acid and brassinosteroid was found to be efficient in boosting NRase activity, which is significantly impacted by drought stress (Fig. 3). Brassinosteroid induced the NRase activity observed in the present study which was in accordance with the results reported in groundnut (28). Reports advocated that BR-induced NRase activity may be the result of improved water status in plants under drought stress. BR induced the nucleic acid metabolism and enhanced the plant growth (26) whereas application of salicylic acid protects the NRase activity by induced conservation of water was observed in tomato under stress condition (29). This is in confirmation with previous findings in finger millet and in blackgram who reported that foliar spray of BR improved the NRase activity (30, 31).

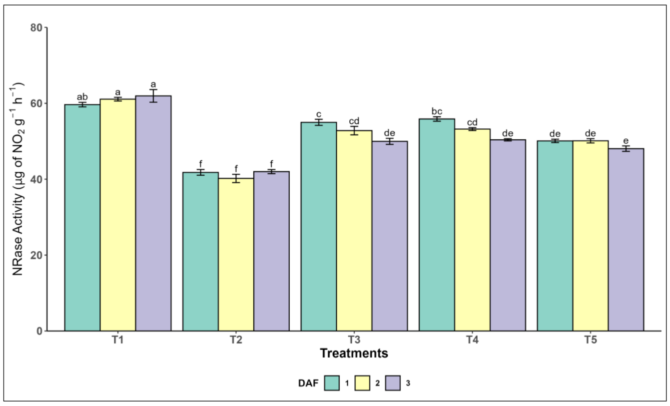

Fig. 3. Effect of PGRs on NRase activity in finger millet under flowering stage stress condition (DAF - Days after Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

Proline is normally accumulating in large amounts in response to environmental stress (32). Under stressful conditions, proline accumulation affects protein salvation and preserves membrane integrity. It also mitigates oxidation of lipid membranes or photoinhibition, protects the structure of proteins under drought stress. Therefore, these solutes are vital in osmoregulation. Proline accumulation may help with osmotic adjustment at the cellular level (33, 34) and proline buildup was increased in this study by the application of brassinosteroid (Fig. 4). This is confirmation with the previous findings which observed that the application of BR increased the proline accumulation in sheep grass (35).

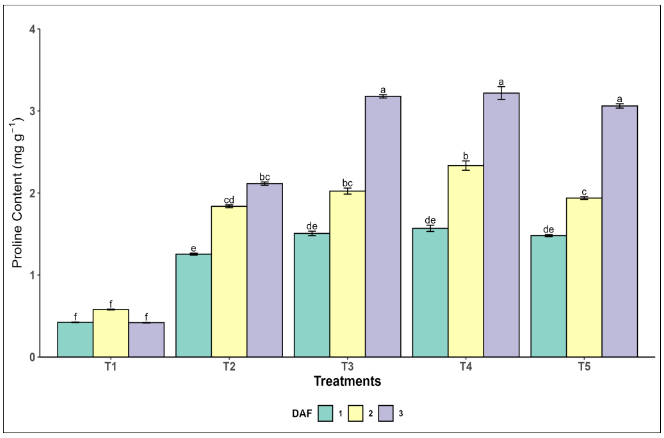

Fig. 4. Effect of PGRs on proline content in finger millet under flowering stage stress condition (DAF - Days after Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

Malondialdehyde (MDA) content significantly increased under drought condition in finger millet. In the present study, foliar spray of BR has a greater potential to mitigate oxidative stress, which lessens their susceptibility to water scarcity. According to our findings, applying salicylic acid and brassinosteroid may enhance the plant's antioxidant defence system by lowering the MDA content (Fig. 5). BR induced regulation of transcription and translation which improves the total proteins and enzyme antioxidants and reduction in MDA content. These results were like the findings in marigold (36) and linseed (37).

Superoxide dismutase (SOD) activity also increased by the application of brassinosteroid (Fig. 6). Brassinosteroid enhanced the expression of biosynthetic genes of these enzyme and increased oxidation was reported (38, 39) These findings, along with a reduction in lipid peroxidation and elevated proline

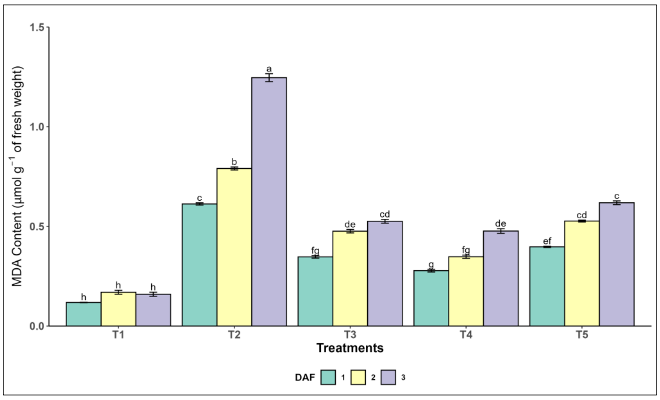

Fig. 5. Effect of PGRs on MDA content (μ mol g^{-1} of fresh weight) in finger millet under flowering stage stress condition (DAF - Days after Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

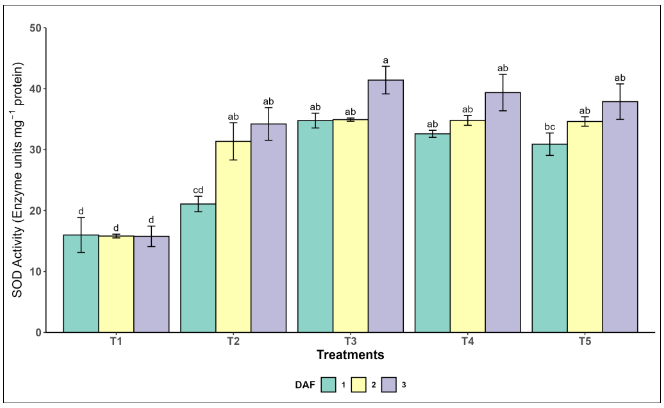

Fig. 6. Effect of PGRs on SOD activity (Enzyme units mg^{-1} protein) in finger millet under flowering stage stress condition (DAF - Days after Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

levels, are indicative of the elimination of stressful situations by the activation of SOD enzymes that protect against damage with the application of brassinosteroid. Similarly, it has been observed that brassinosteroid application caused an increase in CAT activity in sorghum under osmotic stress (40). Total proteins and enzymatic antioxidants increased because of BR-induced transcriptional and translational regulation (41). Salicylic acid increases the catalase and SOD activities and increases the plant tolerance to environmental stress (42). Salicylic acid shields the photosynthetic apparatus from ROS induced damage when there is a water deficit condition and protect the plant from injury (43). Our results agreed with the previous research which demonstrated BR application was able to improve the antioxidant enzymes activity in rice (44).

Growth and yield attributes showed positive response to plant growth regulators under water deficit condition. PGRs help in mitigation of water stress and exhibited less yield reduction in wheat (26). Yield improvement by PGRs could be improved the source activity, sink strength and assimilate partitioning (12). In the present study, BR increased the ear length, ear head weight and grain yield which was on par with SA and chlormequat chloride application (Fig. 7). The result of the present study was in conformity with the findings of Sairam (26) in wheat and researcher reported that the application of PGRs enhanced the

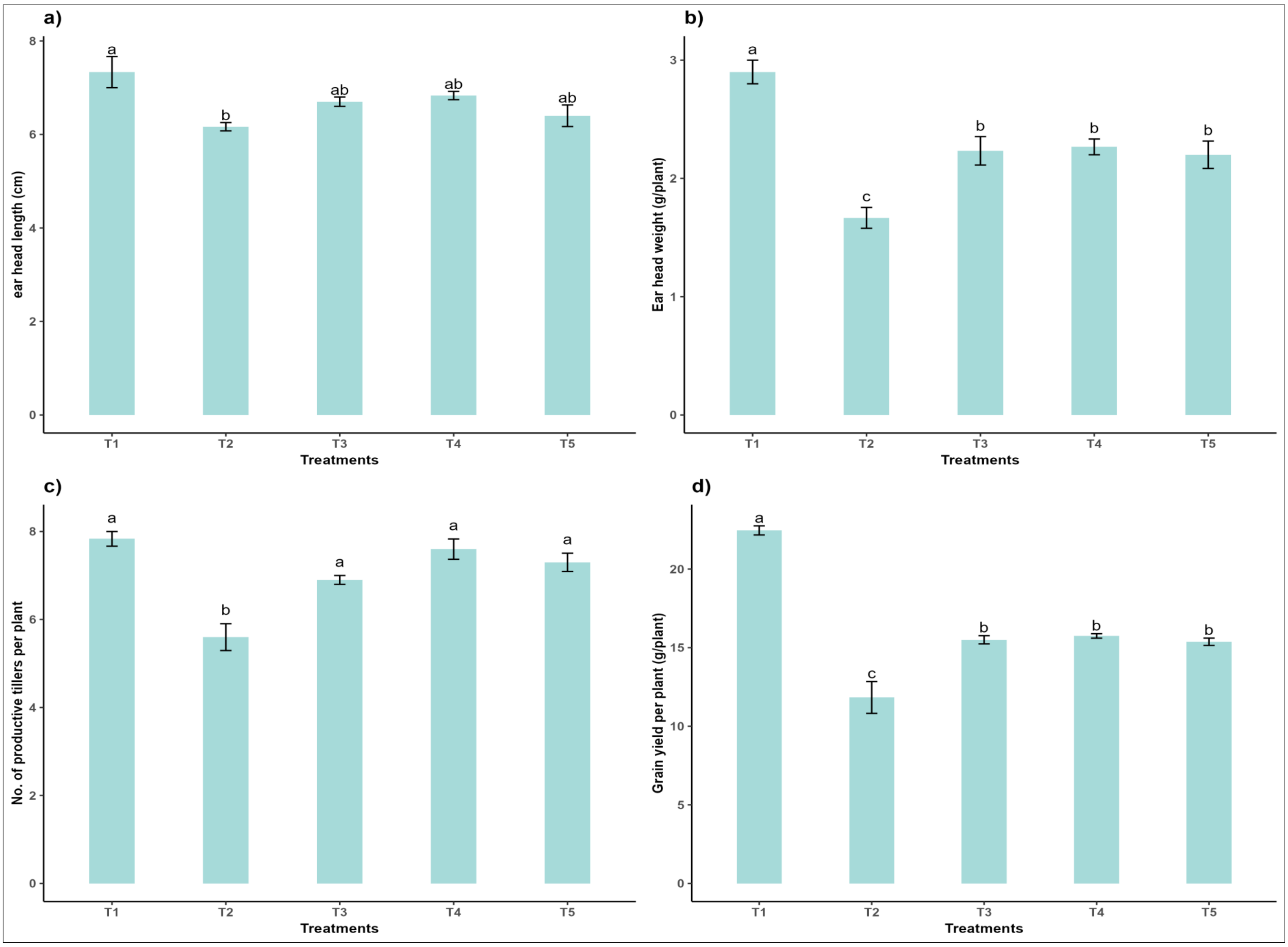

Fig. 7. Effect of PGRs on yield attributes in finger millet under flowering stage stress condition (DAF - Days after Foliar application); Different letters in graphs denote significant differences between treatments (LSD test, $p < 0.05$).

partitioning efficiency which in turn increased the grain yield in pearl millet (12).

Conclusion

In conclusion, foliar spray of brassinosteroid (0.3 ppm) was found to be effective in improving the physiological and biochemical aspects by exhibiting better yield and yield attributes which was on par with salicylic acid (100 ppm) and chlormequat chloride (200 ppm) under drought condition in finger millet. Hence, this kind of strategy might be followed to improve the crop yield which in turn will reflect in the livelihood of the farming community.

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None

Authors' contributions

NS carried out the experiment and drafted the manuscript. KK carried out the statistics and graphical presentation. SN Editing the manuscript. CT performed the statistical analysis. RA attended the editing work and coordination. SK and GS participated in editing the manuscript and sample analysis. AS and VBR performed the lab work.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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