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Effect of Boron, NAA and GA on Spikelet Sterility and Yield in Rice (*Oryza Sativa* L.)

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ABSTRACT

A field experiment was carried out at Agricultural college farm, Bapatla during kharif, 2014-15 to study the influence of boron, NAA and GA_3 on spikelet sterility and yield in rice, Var. BPT 2270 (Bhavapuri sannalu). The experiment was laid out in randomized block design with thirteen treatments viz., boron @ 0.2 ppm at panicle initiation stage (PI) and first flowering stages (T_1 and T_2), boron @ 0.4 ppm at PI and first flowering stages (T_3 and T_4), NAA @ 5.0 and 8.0 ppm, each at PI and first flowering stages (T_5, T_6, T_7 and T_8) and GA_3 @ 300 and 450 ppm, each at PI and first flowering stages (T_9, T_{10}, T_{11} and T_{12}) and control (i.e. water spray- T_{13}) in three replications. The results of the study revealed that, the number of panicles m^{-2} was increased by 108 and 106, and number of spikelets panicle^{-1} increased by 31.3 and 27.4 per cent with GA_3 foliar spray @ 450 ppm at first flowering stage and boron @ 0.2 ppm at panicle initiation stage, respectively, over control. The highest filled grains percentage (75.55 %) was recorded with boron @ 0.2 ppm at panicle initiation stage, followed by boron @ 0.4 ppm (75.08 %). GA_3 foliar sprays were also at par with boron sprays, recorded filled grains percentage in the range of 73.05 to 74.64 %. Lesser sterility percentage was recorded with boron sprays @ 0.2 ppm (24.45 %) and 0.4 ppm (24.92 %) at panicle initiation stage sand GA_3 @ 450 ppm at first flowering stage (25.36%). Foliar spray of boron @ 0.2 ppm at panicle initiation stage and GA_3 @ 450 ppm at first flowering stage increased the test weight of rice grains by 1.11 and 1.07 g, respectively, over control. Grain yield of rice was increased by 28.1, 22.3 and 20.9 per cent with foliar spray of GA_3 @ 450 ppm at first flowering stage, boron @ 0.2 ppm and GA_3 @ 450 ppm at panicle initiation stage, respectively, over control.Hence, it can be concluded that the foliar application of GA_3 @ 450 ppm at panicle initiation and at first flowering stages and boron @ 0.2 ppm at panicle initiation stage increased the grain yield of rice, Var. BPT 2270 (Bhavapuri sannalu) by reducing the spikelet sterility and increasing the filled grains percentage in panicles, and other yield components.

Key words: *Boron, GA_3, NAA, Rice, Spikelet sterility and Yield.*

Rice (*Oryza sativa* L.) is one of the world's most important food crops and a primary source of food for more than half of the world population. In India, rice is cultivated over an area of about 437.71 lakh ha, with an average production of 96.43 million tonnes and a productivity of 2.20 t ha^{-1} (http://dacnet.nic.in). In Andhra Pradesh, rice is cultivated in an area of 43.87 lakh ha with a production of 121.42 lakh tonnes and productivity of 3.12 t ha^{-1} (http://agri.ap.nic.in).Rice contributes 43 per cent of total food grain production and 46 per cent of total cereal production in India.

Yield is a polygenically controlled complex character and highly influenced by genotype and environment interactions. The crop suffers from various biotic and abiotic stresses. The effect of such stresses generally manifests in increased spikelet stertility which decreases the productivity of the crop. Spikelet sterility is one of the poorly understood complex problems in rice. Spikelet sterility and grain filling are two opposite but interrelated phenomenon influencing rice yields. Factors responsible for partial grain filling and spikelet sterility in rice despite evolving modern cultivars and hybrids, were found to be variable. In rice mature panicles, at a given time it is possible to find unopened, sterile (due to lack of ovules or anthers in case of hybrids), partially filled grains and filled grains. In general, the factors such as insufficient assimilate supply, non-fertilization, the rate of accumulation of assimilates, compact or loose panicle types, low temperature, low light intensity, time of flowering and hormonal levels determine the percentage grain filling in rice.

Generally, in Andhra Pradesh rice varieties producing an average of 300 panicles m^{-2} and 100 spikelets per panicle, showed spikelet sterility of 15 per cent at maturity, indicating the scope for improving spikelet fertility. Out of many constraints, the deficiency of boron is one of the reasons for spikelet sterility. Boron is an essential micronutrient for plant and its availability in soil and irrigation determines agricultural production. The main functions of boron in plant relate to sugar transport, flower production, retention, pollen tube elongation and germination, translocation of carbohydrates and sugars to reproductive organs, which in turn improved the spikelet number and spikelet fertility that influenced the yield and productivity (Ahmad *et al.*, 2009).

The introduction of chemical growth regulators has added a new dimension to the possibility for improving the growth and yield of rice crop. Plant growth regulators generate metabolic and physiological responses by affecting their growth and development (Hayat *et al.*, 2010). These are proved to improve effective partitioning and translocation of assimilates from source to sink in field crops. Naphthalene acetic acid (NAA) is a synthetic auxin as it plays a key role in cell elongation, cell division, vascular tissue differentiation, root initiation, apical dominance, delaying leaf senescence, preventing leaf and fruit abscission, fruit setting and flowering (Davies, 1987). It affects the growth, development and other physiological and biochemical processes of plants. It has been used for the enhancement of growth and yield of cereals. Reddy *et al.* (2009) reported that the application of NAA increased yield and yield components of rice.

Gibberellins are plant hormones that participate in regulation of many growth and developmental processes in various plants, involved in seed germination, hypocotyl elongation, leaf expansion, floral initiation, uniform flowering, floral organ development, increased flower number and size and induction of some hydrolytic enzymes in the aleurone layer of cereal grains.

Bhavapuri sannalu (BPT 2270), a high yielding paddy variety developed and released from Rice Research Unit, Bapatla is a semi-dwarf, compact and heavy tillering plant with strong and non-lodging culm. It produces about 350-400 ear bearing tillers per square meter and the number of grains per panicle ranges between 300-350. It matures in about 160-165 days. But due to late release of canal water in Krishna Western delta in recent years, transplanting is delayed and flowering period extends up to the second fortnight of December that coincides with low night temperatures and limited sunshine hours which cause increased sterility percentage in this variety, that limits the yield. Hence, the present study was taken up to investigate the effect of boron and exogenously applied plant growth regulators (NAA and GA_3) in improving spikelet fertility and yield of BPT 2270.

MATERIAL AND METHODS

The field experiment was carried out during kharif, 2014 at Agricultural College Farm, Bapatla. The experiment was laid out in a randomized block design with thirteen treatments Viz., boron @ 0.2 ppm at panicle initiation stage (PI) and first flowering stages (T_1 and T_2), boron @ 0.4 ppm at PI and first flowering stages (T_3 and T_4), NAA @ 5.0 and 8.0 ppm, each at PI and first flowering stages (T_5, T_6, T_7 and T_8) and GA_3 @ 300 and 450 ppm, each at PI and first flowering stages (T_9, T_{10}, T_{11} and T_{12}) and control (i.e. water spray- T_{13}) in three replications.

Rice Var. BPT 2270 (Bhavapuri sannalu) was selected for this study. Dry seed was sown uniformly on nursery bed on 04-08-2014. The nursery (80 m^2) was fertilized with a basal dose of one kg each of N, P and K. Weeding and plant protection measures were taken up as and when necessary. Rice seedlings of 30 days old were transplanted in experimental plots keeping two seedlings per hill by adopting the spacing of 20 cm ×15 cm. The recommended dose of 160 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied through urea, single super phosphate and muriate of potash, respectively. Prophylactic measures were taken up regularly to prevent the incidence of pests, diseases and weeds. Five representative hills were selected randomly and tagged in each plot, and post harvest observations were recorded on the tagged hills. Total number of panicles $hill^{-1}$ from the labeled plants was counted, and expressed as total number of panicles m^{-2} at harvest. Number of spikelets/grains per each panicle was counted for ten randomly selected panicles from each sample and average was calculated. Number of filled grains per each panicle was counted for ten randomly selected panicles from each sample and the average was calculated and expressed in percentage. Filled and unfilled spikelets were counted separately from 10 randomly selected panicles from the net plot and per cent sterility was calculated.

$$\text{Sterility (\%) Percentage} = \frac{\text{No.of sterile spikelets panicle}^{-1}}{\text{Total no.of spikelets panicle}^{-1}} \times 100$$

From the dry seed lot of each plot, samples of 1000- grain weight (g) were taken and weighed. Grain yield was recorded from each plot after threshing followed by sun dryig to a constant weight and expressed in $Kg.ha^{-1}$. The data were statistically analysed using Fisher's method of analysis of variance as outlined by Panse and Sukhatme (1978) for randomized block design. Statistical significance was tested by applying F- test at 0.05 level of probability. Critical differences at 0.05 level were worked out for the effects, which were significant.

RESULTS AND DISCUSSION

Number of panicles m^{-2} was significantly influenced by various treatments of boron, NAA, and GA_3 at panicle initiation and at first flowering stages. Among the various treatments, foliar spray of GA_3 @ 450 ppm at first flowering stage (T_{12}) produced the highest number of panicles m^{-2} (497.67). It was, however, statistically at par with all other treatments, except that of NAA @ 5.0 ppm at panicle initiation stage, which produced the lesser number of panicles m^{-2} (426.67) and it was at par with water spray (i.e., control). The lowest number of panicles m^{-2} (390) was recorded with T_{13} (water spray). Foliar application of GA_3 @ 450 ppm at first flowering stage and boron @ 0.2 ppm at panicle initiation stage increased the number of panicles m^{-2} by 108 and 106, respectively, over control. Shelp *et al.*(1993) reported enhanced translocation of photosynthates from leaves to other plant parts in presence of a sufficient quantity of boron nutrition.

Statistical analysis of the data showed that the foliar application of GA_3 @ 450 ppm and boron @ 0.2 and 0.4 ppm at panicle initiation and first flowering stages significantly increased the number of spikelets panicle^{-1} over control. Maximum number of spikelets per panicle (438.67) were recorded when GA_3 was sprayed @ 450 ppm at first flowering stage (T_{12}) followed by boron @0.2 ppm at panicle initiation stage (T_1- 425.67). The minimum number of spikelets per panicle (334.00) was obtained with water spray (i.e., control). The remaining treatments (T_5, T_6, T_7, T_8, and T_9) were significantly superior over control and inferior over boron and GA_3 sprays. Number of spikelets panicle^{-1} increased by 31.3 and 27.4 percent, with GA_3 @ 450 ppm at first flowering and boron @0.2 ppm at panicle initiation stages, respectively, over control. The increase in number of spikelets panicle^{-1} with GA_3 could be due to the role of GA in flower induction and fruit and seed development (Davies,2005; Fleet and Sun, 2005). Tian and Zhou (1991) reported that GA_3 application greatly influenced the panicle and spikelet exsertion, stigma exsertion, stigma longevity and receptivity, which improved the percentage of seed set in rice hybrids. In the present study, the increase in number of spikelets panicle^{-1} was ranged from 20.6 to 27.4 per cent with boron foliar sprays (@ 0.2 and 0.4 ppm, each at panicle initiation and at flowering stages) compared to control. Similar increase in number of spikelets per spike was also reported by Uddin *et al.*(2008) and Rehman *et al.*(2012), who reported that boron application increased the number of spikelets per spike in wheat. This could be the reason that boron plays a vital role in flowering and grain setting of wheat.

The data recorded on normal kernels percentage/filled grains percentage are presented in Table 1. The data revealed that, except the treatments T_5, T_7 and T_8, the remaining treatments were at par with each other and significantly higher than control. Foliar application of boron @ 0.2 ppm at panicle initiation stage recorded maximum normal kernels percentage (T_1-75.55%) followed by boron @ 0.4 ppm (T_3-75.08%). Lowest normal kernels percentage (66.81%) was recorded in the control plots. Foliar application of NAA @ 5.0 ppm at panicle initiation stage and NAA @ 8.0 ppm at both the stages recorded significantly higher percentage of normal kernels than control plants, but lower than other treatments. Foliar application of boron @ 0.2 and 0.4 ppm each at panicle initiation and at first flowering stages increased the percentage of normal kernels from 74.06 to 75.55. Mitra and Jana (1991) reported that boron application significantly increased the number of grains per spike in wheat. This may be due to the reason that, boron plays a vital role in grain setting of wheat, so, the supply of boron at this stage helps in grain filling and ultimately sterility is reduced and number of grains per spike increased. Application of boron enhanced pollen germination and grain setting at booting stage in wheat (Tahir *et al.*, 2009). As the boron requirement of male reproductive organs, the anthers was also greater than carpel, since the boron requirement in the anthers for successful fertilization was met by application of boron at booting stage, which resulted in higher percentage of filled grains in rice.

Foliar application of GA_3 @ 300 and 450 ppm recorded the normal kernels percentage in the range of 73.05 to 74.64 at both stages of application. GA_3 application greatly influenced the panicle and spikelet exsertion, stigma exsertion, stigma longevity and receptivity which improved the seed set in rice (Gavino *et al.*, 2008). Chenniappan *et al.* (2004) reported that foliar application of GA_3 recorded higher seed set in rice.

Among the various treatments, lesser sterility percentage was recorded with the foliar application of boron @ 0.2 ppm at panicle initiation stage (T_1 - 24.45%) followed by boron @ 0.4 ppm at panicle initiation stage (T_3 - 24.92%) and GA_3 @ 450 ppm at first flowering stage (T_{12} - 25.36%). The remaining treatments, except T_5, T_7 and T_8, were at par with T_1 treatment. The higher sterility percentage was obtained with control (water spray -33.19 %). Foliar application of NAA @ 5.0 ppm at panicle initiation stage and 8.0 ppm at both the stages recorded higher sterility percentages (27.77, 29.33 and 27.85%, respectively) than T_1, T_3 and T_{12} treatments, and lesser sterility percentages than control plants.

In general, more number of fertile spikelets is closely associated with high yield per plant resulting in high productivity. In the present study, the range of sterility percentage varied from 24.45 to 25.94% with the foliar application of boron at 0.2 and 0.4 ppm each at panicle initiation and at first flowering stages. This lower sterility percentage could be due to higher percentage of normal kernels with the application of boron (Table 1). Application of boron enhanced pollen germination, pollen tube growth and grain setting at booting stage in wheat (Tahir *et al.*, 2009). Boron is an essential micronutrient which enhanced the translocation of photosynthates from source to sinks (i.e. to the reproductive organs), which in turn improved the spikelet number and spikelet fertility in rice (Ahmed *et al.*, 2009).

Foliar application of GA_3 @ 300 and 450 ppm at panicle initiation and at first flowering stages also recorded lesser sterility percentages in the range of 25.36 to 26.95%. Application of GA_3 influences panicle exertion, spikelet opening angle and other floral traits which helped in achieving higher yield in rice (Tiwari *et al.*, 2011). GA_3 application greatly influenced the panicle and spikelet exsertion, stigma exsertion, stigma longevity and receptivity which improved the percentage of seed set in rice and reduced the spikelet sterility (Gavino *et al.*, 2008). NAA @ 8.0 ppm at both the stages recorded higher sterility percentage i.e., 29.33 and 27.85% compared to boron and GA_3 application. NAA has both stimulatory and inhibitory effect on different yield parameters and it depends on several factors including the varietal difference and concentration of the chemical. The results are consistent with the view that the plant growth regulators can exert quite different effects in different plants (Ridge, 1991). Hence, boron @ 0.2 and 0.4 ppm at panicle initiation stage and GA_3 @ 450 ppm at first flowering stage helped in reducing spikelet sterility by improving the filled grains percentage in the variety BPT 2270 (Bhavapuri sannalu) in the present study.

Data regarding test weight showed significant differences with the application of boron and plant growth regulators. The highest test weight was recorded with the foliar application of boron @ 0.2 ppm at panicle initiation stage (T_1- 15.23 g) followed by GA_3 @ 450 ppm at first flowering stage (T_{12}- 15.19 g). The remaining treatments, except T_7, T_9 and T_{13}, were at par with T_1 and T_{12} treatments. The lowest test weight was recorded with control (T_{13} – 14.12 g). The treatments T_7 and T_9 were at par with control. The weight of 1000-grain depends on size and filling of the grain. The reduction in weight of 1000-grain might be due to less accumulation of photosynthates in the grain.

Foliar application of boron @ 0.2 ppm at panicle initiation stage and GA_3 @ 450 ppm at first flowering stage increased the test weight by 1.11 and 1.07 g, respectively, over control. Gunnes *et al*. (2003) reported that 1000 - grain weight was significantly increased when boron was sprayed on wheat at proper stage. The results are significant because boron requirement at reproductive stage is more than any other stage and ultimately the grain was healthy and gained more weight. Plant growth regulators also increase the mobilization of reserve food materials to the developing sinks through increase in hydrolyzing and oxidizing enzyme activities and lead to yield increase (Jayachandran *et al*.,2000).

Significant differences were observed among the treatments with regards to grain yield of rice. Foliar application of GA_3 @ 450 ppm at first flowering stage recorded highest grain yield (T_{12} - 8.16 t ha^{-1}) followed by boron @0.2 ppm (T_1 - 7.79 t ha^{-1}) and GA_3 @ 450 ppm (T_{11} - 7.70 t ha^{-1}) which were sprayed at panicle initiation stage. Lower grain yield was obtained with control (T_{13} - 6.37 t ha^{-1}). The treatments T_5, T_6, T_7, T_8 and T_9 were at par with control, whereas foliar spray of boron @ 0.2 ppm at first flowering stage and 0.4 ppm at both the stages recorded significantly higher grain yield than control and lesser grain yield than T_{12} treatment.

Foliar application of GA_3 @ 450 ppm at first flowering stage, boron @ 0.2 ppm and GA_3 @ 450 ppm at panicle initiation stage increased the grain yield of rice by 28.1, 22.3 and 20.9 per cent over control. The increase in grain yield due to GA_3 application in the current study was attributed to the enhanced leaf area, dry matter accumulation and increase in yield components (*viz*., number of panicles m^{-2}, number of spikelets $panicle^{-1}$, and more number of filled grains $panicle^{-1}$, lesser sterility percentage and more test weight). The increase in yield with the application of plant growth regulators might be due to increased yield attributes, which in turn resulted from effective translocation of photosynthates. Plant growth hormones also increase the mobilization of reserve food materials to the developing sinks through increasing hydrolyzing and oxidizing enzyme activities and lead to yield increase (Jayachandran *et al.,* 2000). Gavino *et al.* (2008) also reported that GA_3 application was very effective in increasing seed set rate and seed yield through elongation of plant height, promoting panicle and spikelet exsertion, enhancing stigma exsertion and longevity and receptivity.

Foliar application of 0.2 ppm boron at panicle initiation stage increased the grain yield of rice by 22.3 per cent over control. Dunn et al. (2005) obtained higher paddy yield with the sole application of boron @ 2 kg ha^{-1}. Tahir *et al.* (2009) also reported higher grain yield in wheat with foliar application of boron. He stated that the application of boron enhanced pollen germination and grain setting at booting stage in wheat. As the boron requirement of male reproductive organs, the anthers was also greater than carpel, since the boron requirement in the anthers for successful fertilization was met by the application of boron at booting stage, so the grain yield of wheat was higher than control. In the present study, the higher grain yield of rice with the foliar application of GA_3 @ 450 ppm at panicle initiation and at first flowering stages and boron @ 0.2 ppm at panicle initiation stage might be due to more number of panicles/m^2, filled grains/panicle and lesser sterility percentage of grains and more test weight.

CONCLUSION

From the above results, it can be concluded from this study that, the foliar application of GA_3 @ 450 ppm at panicle initiation and at first flowering stages and boron @ 0.2 ppm at panicle initiation stage increased the grain yield of rice Var.BPT 2270 (Bhavapuri Sannalu) by reducing the spikelet sterility and increasing the filled grains number in panicles, and other yield components.

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