ORIGINAL ARTICLE

Growth and yield response of two hybrid rice cultivars to ATONIK plant growth regulator in a Tropical environment

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Abstract

A study was conducted at the Department of Horticulture, KNUST, Kumasi from June to November, 2015 with the objectives to (i) determine the rate of ATONIK plant growth regulator (PGR) suitable for high yield of two varieties of hybrid rice (ii) determine the combined effects of PGR rates and varieties on the growth and yield performance of hybrid rice. A 2 x 5 factorial arrangement in randomized complete block design with three replications was used. The factors were varieties at two levels: Agra Rice and Jasmine 85 and PGR at five levels: ATONIK at 450 ml/ha, ATONIK at 500 ml/ha, ATONIK at 550 ml/ha, ATONIK at 0 ml/ha and GA_3 at 60 ml/ha. Comparing the ATONIK rates with the GA_3, ATONIK at 450 ml/ha resulted in a 14.3 % increase in the number of rice panicles. Application of ATONIK at 450 ml/ha, 500 ml/ha and 550 ml/ha resulted in 14.4%, 10.7% and 4.4% higher percentage of productive tillers, respectively, than that produced by GA_3 at 60 ml/ha. ATONIK at 450 ml/ha application led to a 17.8 % increase in grain yield. For the harvest index, application of ATONIK at 450 ml/ha resulted in the highest harvest index of 45 %, significantly greater than the other PGR treatments. In conclusion, the study clearly demonstrated that ATONIK PGR was superior to GA_3 in the vegetative and productive performance of rice. The most suitable rate of ATONIK for increased rice productivity was 450 ml/ha.

Keywords: plant growth regulator, rice, vegetative growth, yield

1. Introduction

Rice (*Oryza sativa* L.) is one of the world's main staple crops, with nearly 2.5 billion people depending on it. Rice is cultivated in many developing countries and is the primary source of income and employment for more than 100 million households in Africa and Asia. In Africa, rice is the fastest growing food source (Nwanze et al. 2006). It provides more than one third of the cereal calorific intake in West Africa.

In Ghana, rice is the second most important cereal after maize and it is fast becoming a cash crop for many farmers (MiDA 2010; Osei-Asare 2010; Bam et al. 1998). Annual per capita consumption

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of rice is growing rapidly from 17.5 kilogram in 1999-2001 to 24 kilogram in 2010-2011 (MOFA 2011a), and its demand is projected to be at a rate of 11.8 percent in the medium term (MiDA 2010). Nonetheless, the totality of rice grain obtained from the local rice fields only meet about 40% of the country's rice demand, making Ghana a net importer of the commodity (FAO 2008). These low rice yields have been attributed in part to inadequate nutrition for the growing plant particularly at the reproductive stage where the nutritional demand of the plant tremendously increases (Al-Hassan 2008; Bam et al. 1998; MOFA 1999; MOFA 2000). This situation of consistent low yields can however be overcome through the exploitation of hybrid varieties in the farmers cropping systems. In recent times, farmers are adopting the use of hybrid rice varieties because of their perceived potential to produce high yields. However, these high yields are achieved through an expression of the hybrid vigour of the varieties which are being effectively exploited and sustained through the use plant growth regulators (PGR). Plant growth regulators are organic compounds, other than nutrients, that modify plant physiological processes and are active at very low concentrations in plants (Gianfagna 1987). They act inside plant cells and play important roles in plant growth, yield and quality formation of crops (Ekamber and Kumar 2007). Furthermore, PGRs regulate the amount, type and direction of plant growth with remarkable accomplishments of improved plant development and enhanced yield in several crops been documented (Shah et al. 2006; Emongor 2007). For instance, Auxin, a PGR, regulators cell elongation, tissue swelling, cell division and formation of adventitious roots, among others (Woodward and Bartel 2005; Abel and Theologis 2010). Similarly, Gibberellic acid, another PGR, participates in the regulation of many growth and development processes in various plants, including rice (Richards et al. 2001; Sakamoto et al. 2004; Sun 2004). Rajendra and Jones Jonathan (2009) also reported that application of plant growth regulators could improve the photosynthetic capacity, delay the leaf senescence and promote the rate of rice seed-setting. Presently, in Europe, Asia, the Middle East and the Americas, a plant growth regulator that has been commercialized for the treatment various annual and perennial crops is ATONIK. Studies on ATONIK show positive effects on (i) vegetative growth of seedlings, shoots, roots and branches (ii) reproductive growth in number of flowers and number of fruits and (iii) biomass accumulation (both fresh weight and dry matter) and yield (Arysta Life Science 2014). Presently it is used in the cultivation of oilseed rape, potato, sugar beet, sunflower, maize, soybean, fruit trees, berries, olives, grapes, citrus, cucurbits, solanaceous, leafy and root vegetables. However, for rice, there is a dearth of information on the use of ATONIK.

The objectives of this study therefore were to (i) determine the rate of ATONIK PGR suitable for high yield of two varieties of hybrid rice (ii) determine the effects of ATONIK PGR and GA3 on the growth performance of two varieties of hybrid rice and (iii) determine the combined effects of PGR rates and varieties on the growth and yield performance of hybrid rice.

2. Methodology

2.1. Experimental location

The study was conducted at the Department of Horticulture, KNUST, Kumasi from June to November, 2015. The site is in the semi-deciduous forest zone with an elevation of 186m above sea level (ASL) and a bimodal rainfall distribution. The major rainy season is from late March to mid-July. There is a short dry spell from mid-July to mid-September followed by the minor rainy season from mid-September to mid-November. The mean annual rainfall is 1500mm. The mean minimum and maximum temperatures are 21^{0}C and 31^{0}C, respectively. The mean annual relative humidity is 95% in the morning and about 60% at noon. The soil at the experimental site is ferric Acrisol.

2.2. Experimental design

A 2 x 5 factorial arrangement in randomized complete block design with three replications was used for the experiment. The factors were varieties at two levels: Agra Rice and Jasmine 85 and PGR at five levels: ATONIK at 450 ml/ha (32.4 µl/l of water per plant per application), ATONIK at 500 ml/ha (36.0 µl/l of water per plant per application), ATONIK at 550 ml/ha (39.6 µl/l of water per plant per application), ATONIK at 0 ml/ha and GA_3 at 60 ml/ha (4.32 µl/l of water/plant). The active ingredients of ATONIK are Sodium para-nitrophenolate, Sodium ortho-nitrophenolate and Sodium 5-nitroguaiacolate. The experiment was set up in plastic basins where each basin represented a plot.

2.3. Experimental procedure

Nursery management

Seeds of the two varieties, were obtained from the CSIR-Crops Research Institute, Fumesua. The nursery was carried out in nursery trays in the plant house at the Department of Horticulture. Rice husk ash was used as the media. The seeds were sown on 6th July, 2015 at the rate of one seed per tray hole. The seeds were slightly covered with the rice husk and watered regularly. At 4 and 7 days after sowing, 98% germination was achieved for Jasmine 85 and Agra Rice, respectively.

Preparation of plastic basins for planting and transplanting

Top soil dug from the Department was sieved to remove plant debris, plastic materials and broken glasses. The sieved soil was put in a metal container tray and sterilized for 30 minutes at 100ºC. The sterilized soil was then spread on a large tarpaulin, covered and left overnight to cool. Plastic basins each measuring 60cm (diameter) x 70cm (height) was filled with 21.3 kg of the cooled sterilized soil. Thorough watering was then done to allow the soil to settle prior to transplanting. On 14th July, 2015, the rice seedlings were transplanted into the soil and watered. At fortnightly interval, a hand fork was used to stir the soil to enhance soil aeration. On 3rd August, 2015, 21 days after transplanting, compound fertilizer (NPK 15-15-15) was applied to the seedlings at a rate of 1.2 g per plant. Watering was done judiciously in the mornings and late afternoons and weeds were handpicked every two weeks. The ATONIK treatments were applied on two occasions on 11th August, 2015 (30 days after transplanting) and on 10th September, 2015 (60 days after transplanting). The GA_3 at 60 ml/ha was applied on 7th October, 2015, at heading of rice. Both ATONIK and GA_3 were applied as foliar spray. Stem borers that attacked the rice plants were controlled using Farin (*Chlorpyrifos*) at a rate of 20 ml l^{-1} of water on 20th and 27th September, 2015. Rice blast attack was controlled using Goldazim (*Cabendazim*) at a rate of 10 ml l^{-1} of water on 11th, 18th and 25th September, 2015. Harvesting was done on 17th November for Jasmine 85 and 24th November for Agra Rice. Data were collected on the following parameters; (i) Plant height (cm) – using a metre rule the height of the ten rice plants were measured from the base of the plant (at soil level) to the apex. The plant height was recorded two weeks after transplanting and was repeated for every two weeks (ii) Number of tillers – the number of tillers were counted every two weeks on the same ten plants (iii) Number of productive tillers – the number of tillers that produced panicles were counted and recorded as productive tillers (iv) Number of panicles - the number of panicles on the tillers were counted on the same ten plants (v) Grain weight (g) - the weight of harvested rice grains were obtained using an electronic balance (vi) Harvest index (%) – this was calculated as (dry mass of harvested component / total shoot dry mass) x 100.

2.4. Data Analysis

Data collected were subjected to analysis of variance using Statistix version 9.0. The Least Significant Difference (LSD) was used for mean separation at a probability level set at $p = 0.05$.

3. Results

3.1. Effects of PGR on plant height of two rice varieties

There were significant variety x plant growth regulator (PGR) interactions for plant height at 41 days after transplanting (DAT) (Tab. 1), 48 DAT (not shown), 62 DAT (not shown) and 76 DAT (not shown) and 90 DAT (Tab. 2). At 41 DAT, Agra Rice sprayed with ATONIK at 500 ml/ha produced the tallest plants, significantly greater in height than all the Jasmine 85-PGR treatment combinations but similar to the other Agra Rice-PGR combinations. The shortest plants was produced by Jasmine 85 sprayed with ATONIK at 450 ml/ha. Similar trends were observed until 90 DAT when the trend changed. At 90 DAT, Agra Rice sprayed with ATONIK at 450 ml/ha produced the tallest plants, significantly greater in height than all the Jasmine 85-PGR treatment combinations and the Agra Rice - NO PGR combination but similar to the other Agra Rice-PGR combinations. The shortest plants was also produced by Jasmine 85 sprayed with ATONIK at 450 ml/ha. Generally, Agra Rice plants were significantly taller than Jasmine 85 plants over the period of the study.

Tab. 1 Effect of plant growth regulators on the plant height of two varieties of rice at 41 DAT.

	Agra Rice (cm)	Jasmine 85 (cm)	Mean
Atonik 450	79.70	70.73	75.22
Atonik 500	84.20	75.33	79.77
Atonik 550	81.27	72.93	77.10
GA3	81.13	74.27	77.70
No PGR	79.53	74.33	76.93
Mean	81.17	73.52	
Lsd 5%	PGR = 4.822 ; Variety = 3.050 ; PGR x Var = 6.820		

Tab. 2 Effect of plant growth regulators on the plant height of two varieties of rice at 90 DAT.

	Agra Rice (cm)	Jasmine 85 (cm)	Mean
Atonik 450	101.00	88.53	94.77
Atonik 500	99.93	91.53	95.73
Atonik 550	95.87	90.67	93.27
GA3	95.8	88.67	92.23
No PGR	89.80	86.73	88.27
Mean	96.48	89.23	
Lsd 5%	PGR = 5.754 ; Var = 3.639 ; PGR x Var = 8.136		

3.2. Effects of PGR on shoot and root fresh weight of two rice varieties

There were significant variety x PGR interactions for the shoot weight of rice at 90 DAT (Tab. 3). Jasmine 85 sprayed with GA_3 at 60 ml/ha produced the heaviest shoot weight, significantly greater than all the Agra Rice-PGR combinations as well as the Jasmine 85-ATONIK at 450ml/ha and Jasmine 85-No PGR combinations. The least shoot weight was produced by Jasmine 85 sprayed with ATONIK at 450ml/ha. Generally, application of GA_3 at 60 ml/ha resulted in the highest shoot weight whereas application of ATONIK at 450 ml/ha resulted in significantly the least shoot weight.

There were also significant variety x PGR interactions for the root weight of rice at 90 DAT (Tab. 4). Both Agra Rice and Jasmine 85 sprayed with ATONIK at 450 ml/ha produced the heaviest root weight, significantly greater than the root weight of the other treatment combinations. The lowest root weight was produced by Agra Rice with no PGR application. Generally, application of ATONIK at 450 ml/ha resulted in the production of the greatest root mass whereas no PGR application resulted in the production of the lowest root mass.

Tab. 3 Effect of plant growth regulators on the shoot fresh weight of two varieties of rice at 90 DAT.

	Agra Rice (g)	Jasmine 85 (g)	Mean
Atonik 450	266.0	343.20	304.6
Atonik 500	281.73	382.33	332.03
Atonik 550	288.57	377.07	332.82
GA3	261.60	416.53	339.07
No PGR	269.73	362.53	316.13
Mean	273.53	376.33	
Lsd 5%	PGR = 35.07 ;	Var = 22.18;	PGR x Var = 49.60

Tab. 4 Effect of plant growth regulators on the root fresh weight of two varieties of rice at 90 DAT.

	Agra Rice (g)	Jasmine 85 (g)	Mean
Atonik 450	900	900	900
Atonik 500	850	450	650
Atonik 550	800	450	625
GA3	393.3	650	520
No PGR	400	400	400
Mean	668.7	570	
Lsd 5%	PGR = 22.15;	Var = 14.01;	PGR x Var = 31.32

3.3. Effects of PGR on number of panicles of two rice varieties

There were significant variety x PGR interactions for the number of heads at 90 DAT (Tab. 5). Agra Rice sprayed with ATONIK at 450 ml/ha produced the highest number of heads, significantly greater than either Agra Rice or Jasmine 85 to which no PGR was applied but similar to all the other Agra Rice-PGR and Jasmine 85-PGR combinations. The least number of heads was produced by Jasmine 85 with no PGR application. Generally, application of ATONIK at 450 ml/ha and ATONIK at 500 ml/ha resulted in significantly higher number of panicles than the control (no PGR) but similar to that produced by application of GA_3 at 60 ml/ha.

Tab. 5 Effect of plant growth regulators on the number of panicles of two varieties of rice at 90 DAT.

	Agra Rice	Jasmine 85	Mean
Atonik 450	37.33	36.33	36.83
Atonik 500	34.33	34.0	34.17
Atonik 550	32.67	31.33	32.0
GA3	31.67	32.67	32.17
No PGR	29.33	25.0	27.17
Mean	33.07	31.87	
Lsd 5%	PGR = 5.535 ;	Var = 3.501;	PGR x Var = 7.828

Comparing the ATONIK rates with the GA_3, ATONIK at 450 ml/ha resulted in a 14.3 % increase in the number of panicles produced by rice whiles ATONIK at 500 ml/ha recorded only a 6.2 % increase in the panicle numbers (Fig. 1). Interestingly, ATONIK at 550 ml/l resulted in a decrease in the number of panicles produced as compared with that of GA_3.

However when all the PGRs were compared with no PGR application, ATONIK at 450 ml/ha resulted in a 35.3 % increase in the number of panicles whiles ATONIK at 500 ml/ha recorded a 25.7. % increase in the panicle numbers (Fig. 2). ATONIK at 550 ml/ha and GA_3 at 60 ml/ha also recorded increases of 17.6 % and 18.4 %, respectively.

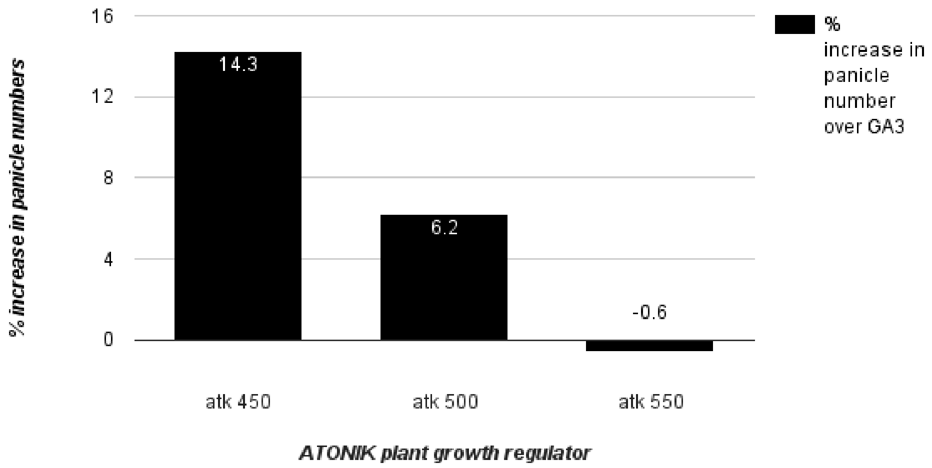

Fig. 1 Percent increase in number of panicles at various ATONIK rates as compared with GA3 rate.

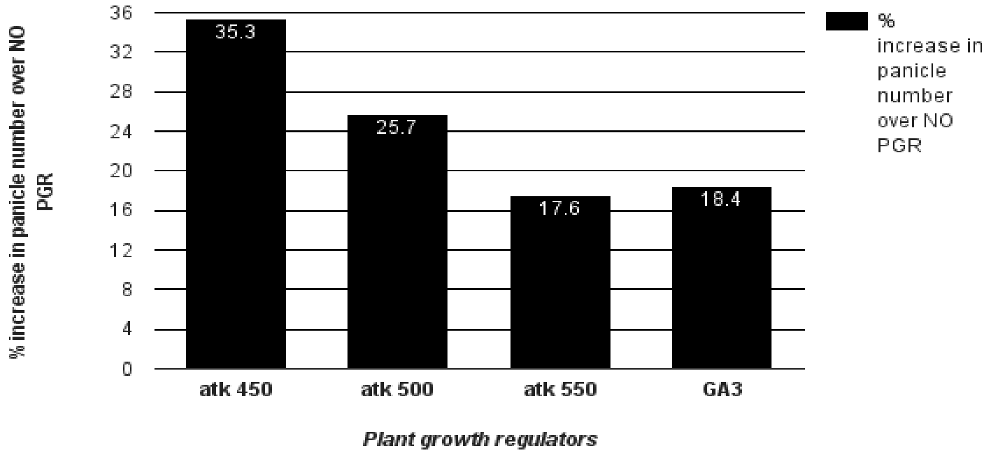

Fig. 2 Percent increase in number of panicles at various PGR rates as compared with NO PGR application.

3.4. Effects of PGR on number of tillers of two rice varieties

There were significant variety x PGR interactions for the number of tillers at 27 DAT (Tab. 6), 41 DAT (not shown), 48 DAT (not shown), 62 DAT (not shown), 76 DAT (not shown) and 90 DAT (Tab. 7). At 27 DAT, Jasmine 85 sprayed with ATONIK at 450 ml/ha produced the greatest number of tillers, significantly higher than all the Agra Rice - PGR treatment combinations but similar to the other Jasmine 85 - PGR combinations. The least number of tillers was produced by Agra Rice sprayed with GA_3. Similar trends were observed until 90 DAT when the trend changed. At 90 DAT, Jasmine 85 sprayed with GA_3 produced the highest number of tillers, significantly greater in number of tillers than all the Agra Rice-PGR treatment combinations, but similar to the other Jasmine 85 -PGR combinations. The least number of tillers was produced by Agra Rice sprayed with GA_3.

Tab. 6 Effect of plant growth regulators on the number of tillers of two varieties of rice at 27 DAT.

	Agra Rice	Jasmine 85	Mean
Atonik 450	24.38	37.8	31.09
Atonik 500	26.73	34.3	30.53
Atonik 550	23.47	32.93	28.2
GA3	22.27	34.2	28.23
No PGR	23.47	34.3	28.9
Mean	24.06	34.72	
Lsd 5%	PGR = 5.040 ;	Var = 3.187 ;	PGR x Var = 7.127

Tab. 7 Effect of plant growth regulators on the number of tillers of two varieties of rice at 90 DAT.

	Agra Rice	Jasmine 85	Mean
Atonik 450	54.87	68.33	61.6
Atonik 500	57.93	60.4	59.17
Atonik 550	52.4	65.0	58.7
GA3	51.73	71.67	61.7
No PGR	44.87	62.77	53.82
Mean	52.36	65.63	
Lsd 5%	PGR = 9.058; Var = 5.729; PGR x Var = 12.809		

Among the PGR treatments, application of ATONIK at 450 ml/ha resulted in the highest percentage of productive tillers followed by ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60 ml/ha (Fig. 3). In comparing the PGR applications with No PGR, the least percentage of productive tillers was produced by the rice where No PGR application was made (Fig. 3). Application of ATONIK at 450 ml/ha resulted in a 14.4 % higher percentage of productive tillers than that produced by GA_3 at 60 ml/ha. Similarly, ATONIK at 500 ml/ha and ATONIK at 550 ml/ha also resulted in 10.7 % and 4.4 % higher percentage of productive tillers than that of GA_3 at 60 ml/ha (Fig. 4). However, when the PGR rates were compared with the no PGR application, the extent of increase in the productive tillers was higher such that application of ATONIK at 450 ml/ha resulted in an 18 % higher percentage of productive tillers than that produced without any PGR application (Fig. 5). Similarly, application of ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60ml/ha resulted in 14.2 %, 7.7 %, and 3.2 %, respectively more productive tillers that that without PGR application.

3.5. Effects of PGR on grain yield and harvest index of two rice varieties

Grain yield of rice was highest under ATONIK at 450 ml/ha application, significantly greater than those under GA_3 at 60 ml/ha and no PGR (Fig. 6). The least grain yield was produced by rice to which no PGR was applied. When the ATONIK rates were compared with GA_3 at 60 ml/ha, ATONIK at 450 ml/ha application led to a 17.8 % increase in grain yield whiles ATONIK at 500 ml/ha and ATONIK at 550 ml/ha led to 14.9 % and 9.2 %, respectively (Fig. 7). However, in comparison to no PGR application, ATONIK at 450 ml/ha application led to a 33.9 % increase in grain yield whiles ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60 ml/ha led to increases of 30.6 %, 24.1 % and 13.7 %, respectively (Fig. 8).

As regards the harvest index, application of ATONIK at 450 ml/ha resulted in the highest harvest index of 45 % which was significantly greater than the other PGR treatments (Fig. 9). In descending order, the harvest indices for the other PGR rates were 40 % (ATONIK at 500 ml/ha), 38 % (ATONIK at 550 ml/ha), 35 % (GA_3 at 60 ml/ha) and 33 % (no PGR) (Fig. 9). When the ATONIK rates were compared with the GA_3 rate, application of ATONIK at 450 ml/ha led to a 28.6 % increase in harvest index whereas ATONIK at 500 ml/ha and ATONIK at 550 ml/ha led to increases of 14.3 % and 8.6 %, respectively (Fig. 10). In comparison to no PGR application, application of ATONIK at 450 ml/ha led to a 36.4 % increase in harvest index whereas ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60 ml/ha led to increases of 21.2 %, 15.2 % and 6.1%, respectively (Fig. 11).

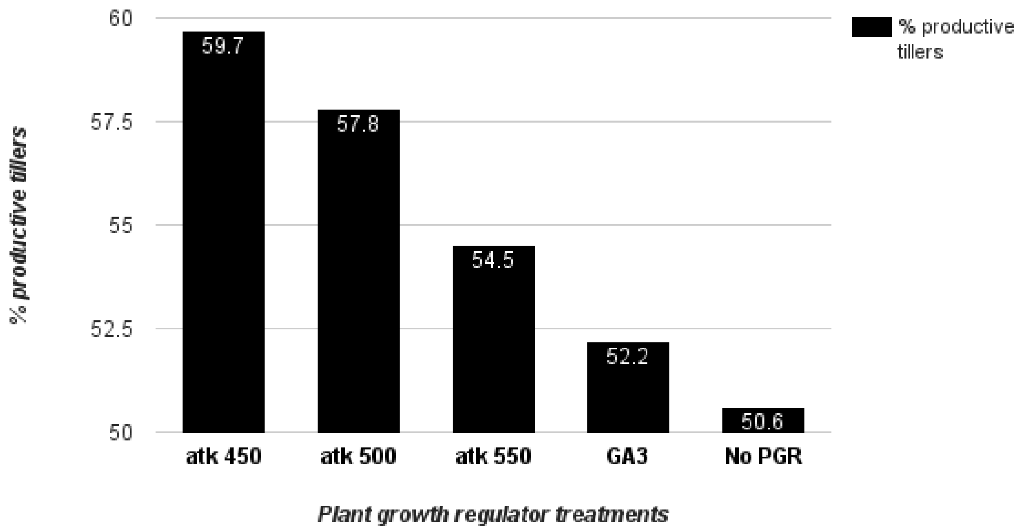

Fig. 3 Percent productive tillers under various PGRs.

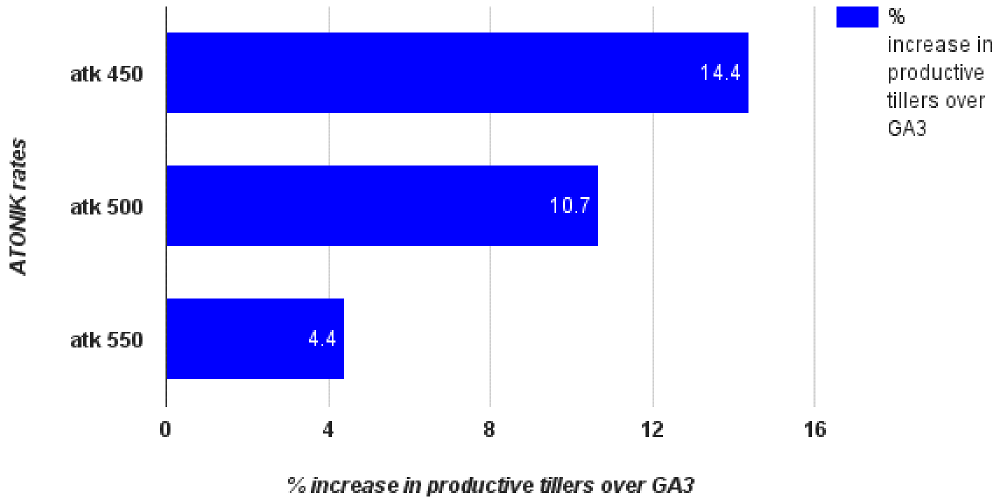

Fig. 4 Percent increase in productive tillers under various ATONIK rates in comparison with GA3.

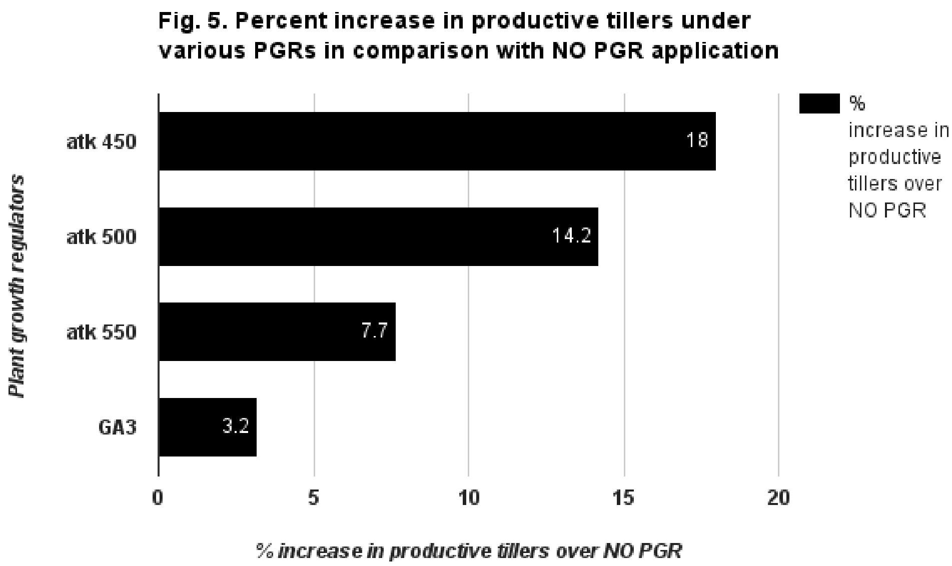

Fig. 5 Percent increase in productive tillers under various PGRs in comparison with NO PGR application.

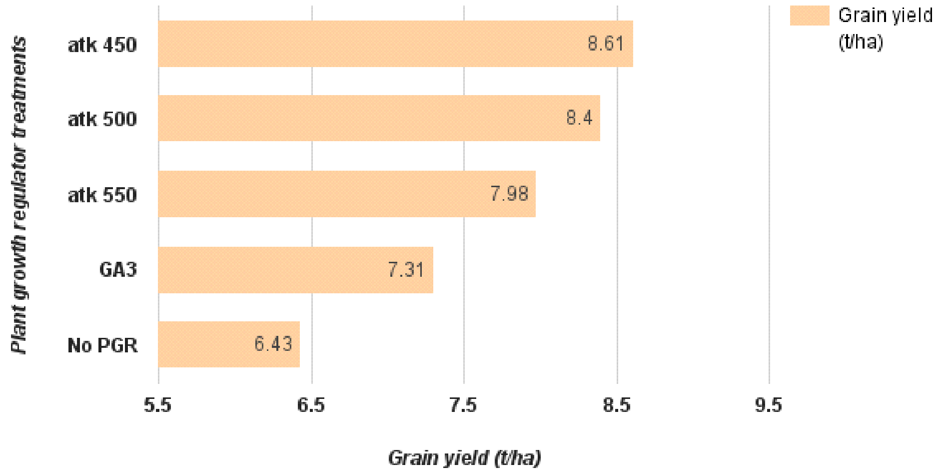

Fig. 6 Grain yield under various PGRs and the control (No PGR).

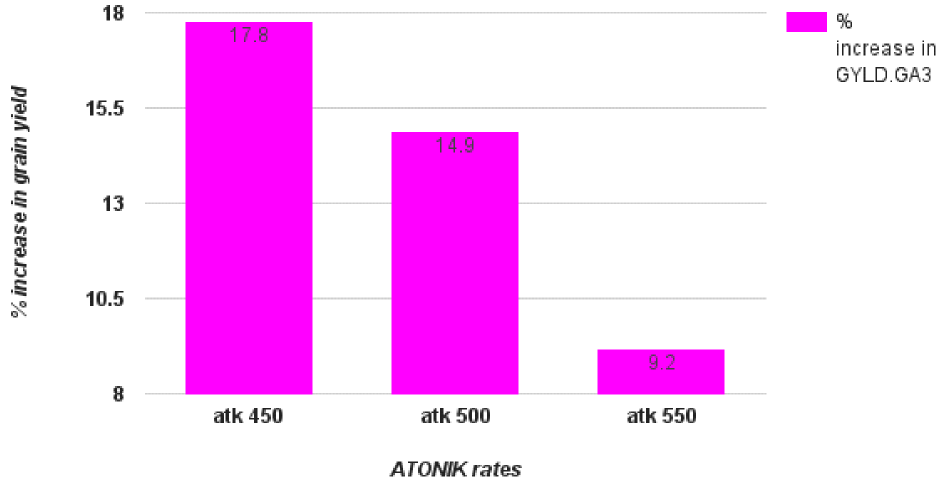

Fig. 7 Percent increase in grain yield under various ATONIK rates in comparison with GA3 rate.

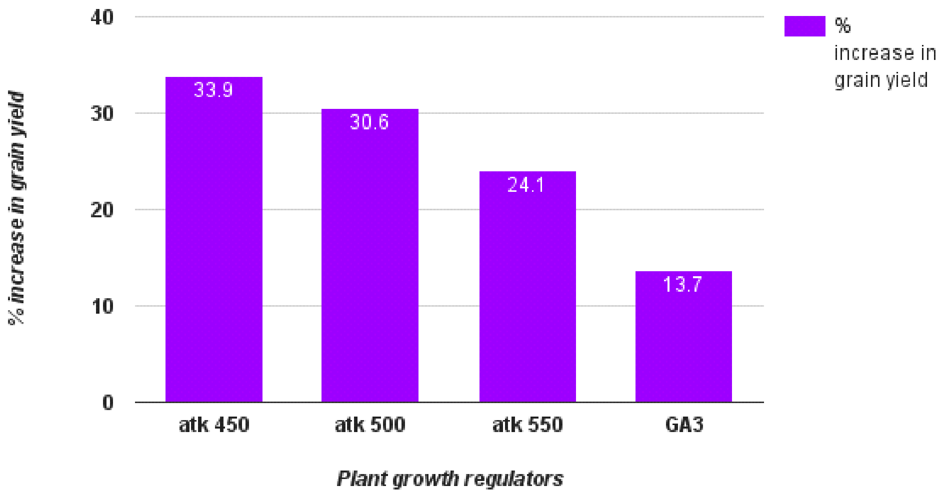

Fig. 8 Percent increase in grain yield under various PGRs in comparison with NO PGR.

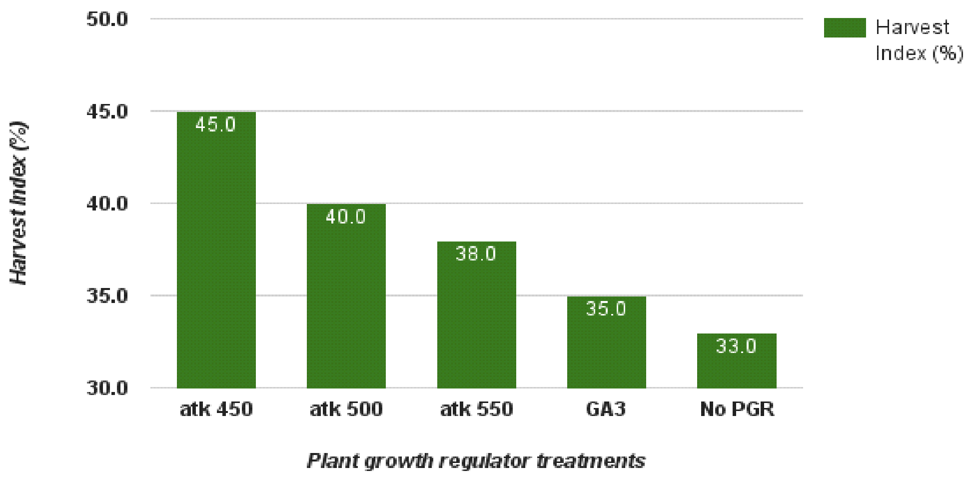

Fig. 9 Harvest index of rice under various PGRs.

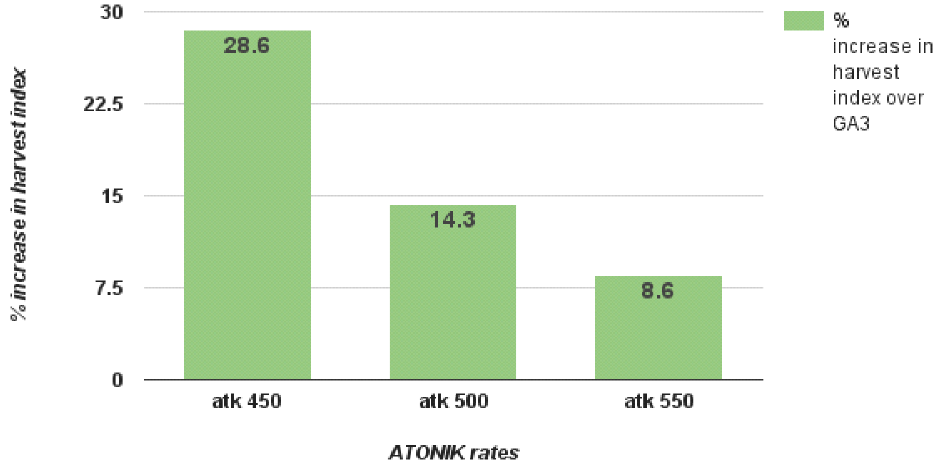

Fig. 10 Percent increase in harvest index of ATONIK rates in comparison with GA3 rate.

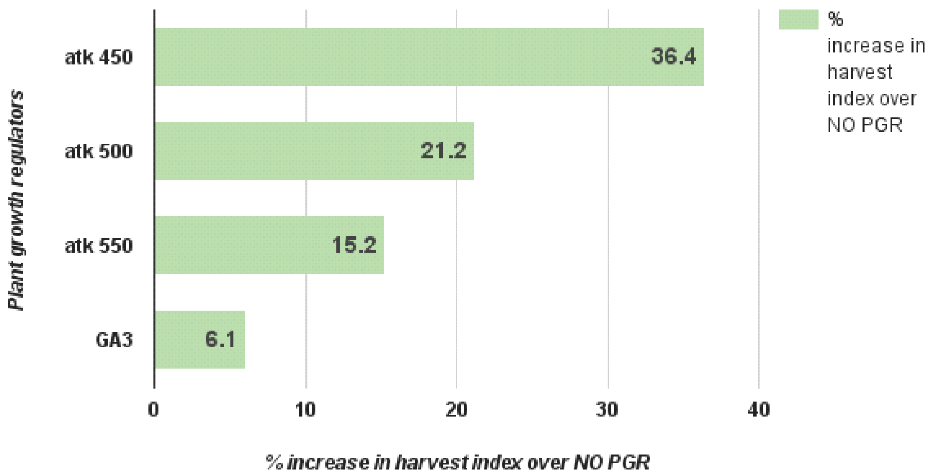

Fig. 11 Percent increase in harvest index of PGRs in comparison with NO PGR.

4. Discussion

Plant growth regulators play important roles in plant growth, development, yield and qualities formation (Ekamber and Kumar 2007; Rajendra and Jones Jonathan 2009). Solaimalai et al. (2001) found that suitable application of plant growth regulators could improve the photosynthetic capacity and promote the rate of rice seed-setting. In the present study, ATONIK PGR was comparable to GA_3

in increasing plant height over the study period. These findings were in close agreement with the results of Subbaih and Mittra (1997) and Dunand (1998) who also reported of significant increases in plant height and stem elongation in rice when plant growth regulators were applied. The increase in plant height could be the result of an enhanced vegetative growth emanating from active cells division, cells enlargement and cells elongation (Pareek et al. 2000). In addition, application of ATONIK at 450 ml/ha resulted in the production of the greatest root mass whereas no PGR application resulted in the production of the lowest root mass. Peng et al. (1999) reported that application of PGR increased root biomass and root activity. All the ATONIK rates and GA_3 rate, resulted in significant increases in the number of panicles, the greatest of 35.5 % being produced from the application of ATONIK at 450 ml/ha. Among the PGR treatments, application of ATONIK at 450 ml/ha resulted in the highest percentage of productive tillers followed by ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60 ml/ha. Rice plants to which no PGR was applied produced the least percentage of productive tillers. Application of ATONIK at 450 ml/ha resulted in a 14.4 % higher percentage of productive tillers than that produced by GA3 at 60 ml/ha. Similarly, ATONIK 500 ml/ha and ATONIK 550 ml/ha also resulted in 10.7 % and 4.4 % higher percentage of productive tillers than that of GA_3 at 60 ml/ha. More effective tillers per plant are believed to be closely associated with high seed yield per plant resulting in high productivity. Hybrid rice relies mainly on tillers to obtain desirable population and about 85-90% of productive panicles of hybrid rice come from tillers (Elankavi et al. 2009). All the PGR rates resulted in increases in grain yield in comparison to no PGR application. In this regard, ATONIK at 450 ml/ha application led to a 33.9 % increase in grain yield whiles ATONIK at 500 ml/ha, ATONIK at 550 ml/ha and GA_3 at 60 ml/ha, led to increases of 30.6 %, 24.1 % and 13.7 %, respectively. Following a similar trend, Elankavi et al. (2009) reported a 13% higher seed yield with application of GA3 at 60 ml/ha in rice. Furthermore, Elankavi et al. (2009) also reported an up to 50.5 % increase in grain yields over no PGR application. Biological yield significantly increases with the application of PGR and larger panicle is associated with high number of grain panicles which culminate in high productivity (Kalavathi et al. 2000; Shi-Hua 2006). Thus when the ATONIK rates were compared with GA_3 at 60 ml/ha, ATONIK at 450 ml/ha application led to a 17.8 % increase in grain yield whiles ATONIK at 500 ml/ha and ATONIK at 550 ml/ha led to 14.9 % and 9.2 %, respectively. Such increases in grain yield might be due to the fact that the ATONIK PGR enhanced the promotion of a more effective translocation of photosynthates produced from an increased mobilization of reserve food materials to the developing sink through an increase in the hydrolyzing and oxidizing activities of enzymes (Jayachandran et al. 2000). Application of PGR also enhances lodging resistance and increases the root activity of rice to improve phosphorus and potassium accumulation in the rice stem, leaves and grains (Peng et al. 1999). In the present study, such enhanced root activity was obtained from the application of the ATONIK which led to harvest index increases of 28.6 % for ATONIK at 450 ml/ha, 14.3 % for ATONIK at 500 ml/ha and 8.6 % for ATONIK at 550 ml/ha comparative to GA_3 at 60 ml/ha.

5. Conclusion

The study clearly demonstrated that ATONIK PGR was superior to GA_3 in the vegetative and productive performance of rice. Consequently, ATONIK application resulted in the tallest plants with the highest number of panicles and productive tillers. In addition, ATONIK application produced an increased root mass which better exploited the soil environment and subsequently culminated in the production of high rice yields with an enhanced efficiency of dry matter partitioning which led to a high harvest indices. The study concludes that application of PGRs are good for increased rice productivity, the best being ATONIK at a rate of 450 ml/ha.

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