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ENHANCING SEED YIELD OF HYBRID RICE BY MAINTAINING ROW RATIO AND DOSAGES OF GIBBERELLIC ACID

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ABSTRACT. The purpose of this study was to identify the optimum levels of gibberellic acid and suitable row ratio for maximization the seed yield of hybrid rice. An experiment was conducted at the experimental farm of Rice Research and Training Center, Egypt, during 2013 and 2014 growing seasons. The material under this study included the parental lines of IR69625A (Female lines) and Giza 179 R (Restorer line) to produce F0 hybrid seeds. A split-plot design with three replications was used. The main plot was row ratio (2R:8A, 2R:10A and 2R:12A) and sub plots was the doses of gibberellic acid (g/ha) (control, 300, 350, 400). The results indicated that, Application of GA_3 and row ratio had significant effect on different traits of seed yield and hybrid seed production. The highest values of flag leaf area, panicle length, seed set, panicle weight, panicle exsertion and seed yield were acheived by using 2R: 8A row ratio and was observed the lowest values were obtained at the 2:12 row ratio. Acoording to gibberellic acid application, the highest values for panicle length (cm), seed set (%), panicle weight (g), panicle exertion (%), harvest index and seed yield were recorded by using 400 g /ha gibberellic acid. Accordingly, the highest net economic return from seed yield was obtained with the treatment combination of 400 g/ha GA_3 x 2:8 (R: A) row ratio.

Keywords: GA3; hybrid seed production, *Oryza sativa*; row ratio.

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important cereal crop with exceptional agricultural and economic importance as being a staple food for half of the world's population (Mohanty *et al*., 2010; Misratia *et al*., 2015). Rice is also used as cereal grain in Central America, Europe and Africa. An increased production of about 50 million tons of rice is necessary per year to face the

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world's demand, while the productivity of rice is not increasing with its raising demand due to population growth (Misratia *et al*., 2015).

Due to over growth of population, rice requirement is increasing dramatically and many nations are facing second-generation challenge of producing more rice at less cost in a deteriorating environment. Therefore, improving technologies are required to achieve the goal of ensuring food security, which is a challenging task. So, enhancing productivity of rice through novel approaches will be necessary (Pan *et al*., 2013). Efforts to meet the rice needs can be done in two ways: expanding the rice growing area, i.e. horizontal expansion, and increasing productivity, i.e. vertical expansion, or both. But in the future, horizontal expansion will be more difficult and expensive. Therefore, special attention should be taken into vertical expansion through improving genetic potential and management practices. It is reported that rice productivity can be increased through the adoption of hybrid rice (Nguyen, 2010; Hasan *et al*., 2015). Rice hybrids with a yield advantage of 20% were developed in China in the 1970s (Yuan, 2011; Pan *et al*., 2013). Hybrid rice is considered as a viable alternative technology for breaking the present yield ceiling of modern varieties (Hasan *et al*., 2010). The success in increasing rice production through hybrid rice has been proven in China. The increase in production is 15-20% higher than the best commercial inbred rice, with a planting area reached more than 50% of the total area (Surahman *et al*., 2014). In China and India, hybrid rice provides a yield advantage of 1.0-1.5 ha^{-1} (20-30%) over the conventional inbred varieties (Virmani, 1994; Hasan *et al*., 2010).

Plant growth regulators play vital roles in coordination of many growth and behavioral processes in rice, which regulates the amount, type and direction of plant growth (Bari and Jones, 2009; Anjum *et al*., 2011; Pan *et al*., 2013). The use of gibberellic acid (GA_3) is becoming popular to ensure efficient production. Remarkable accomplishments of plant growth regulators, such as manipulating plant growth and crop yield have been actualized in recent years (Sarkar *et al*., 2002; Sakamoto *et al*., 2005; Morinaka *et al*., 2006; Peleg and Glumwald, 2011; Pan *et al*., 2013). GA_3 is responsible for stimulating the production of mRNA molecules in the cells, which in turn improves the chances of fast growth (Richards *et al*., 2001; Olszewki and Gubler 2002; Emongor, 2007; Pan *et al*., 2013). GA_3 application helps to complete exsertion of the panicle out of the flag leaf sheath in CMS lines and increased the grain yield at least by 0.870 t/ha, when used 200 g/ha local GA_3, comparing without applied GA_3 (Abo-Youssef, 2003). While, the advantage of hybrid rice cannot be fully utilized unless a cost effective seed production system successfully developed. At present, use of GA_3 is necessary for hybrid rice seed production, which increases the cost of hybrid seeds (Hasan *et al*., 2015).

To produce hybrid seed successfully on commercial scale, male and female parents planted side by side in fixed row ratio should flower simultaneously, which is called synchronization. This synchronization can be achieved by seeding them on different dates (Yuan, 1985; Virmani, 1994; Rahman *et al.*, 2012). In hybrid seed production the seed parent and pollen parent are planted in a certain row ratio and spacing. The row ratio and spacing of pollen parent and seed parent have a distinct effect on the hybrid seed yield. The row ratio or the row proportion refers to the numbers of rows of the male parent (R line) to that of the female parent (A line) in the seed production plot. To facilitate higher outcrossing, it is better to adjust the row direction nearly perpendicular to the wind direction (Hasan *et al*., 2010). Therefore, with keeping the above points in view, the current study aims to standardize the appropriate row ratio for enhancing their optimum-outcrossing rate that could give higher seed yield, as well as to study the optimum dose of GA_3 application to increase the seed production of hybrid rice for enhancing hybrid rice seed production under Egypt condition.

MATERIALS AND METHODS

Experimental design, treatment and parental lines used

This study was conducted at experimental farm of Sakha Agricultural Research Station, Egypt, during the two successive summer seasons of 2013-2014 and 2014-2015. The material under study included two parental lines IR69625A (female A line) with abortive sterility and Giza 179 R (restore R line) to produce F0 hybrid seed for promising hybrid SK.2151H. The experimental was arranged in a split-plot design with three replications. The row ratio (2R:8A, 2R:10A and 2R:12A) was in main plot and the doses of GA_3 (control, 300, 350, 400 g/ha) in was sub plots.

Cultural practices

The pre-germinated seed was uniformly broadcast in the nursery bed on three times for Giza 179 R line (on 17th, 22nd and 27th May for both 2013 and 2014 seasons). To provide adequate pollen load to female sterile line IR69625A, it was sown on 7th May of 2013 and 2014 seasons, sowing variations was followed for complete synchronization of flowering based on the growth duration in previous season as 98±3 for IR69625A line and 87±3 days for Giza 179. The other cultural practices were done as recommended by RRTC, 2008.

Data collection

The crop was harvested and the grains were sun-dried and adjusted at 14% moisture to calculate the yield. The data were recorded per plot randomly selected hills excluding border rows: No. of panicles/hill, panicle length (cm), panicle weight (g), panicle exsertion (%), seed set (%), 1000-grain weight (g), seed yield (t/ha) and harvest index (%). The general reference for data collection was standard evaluation system for rice (SES) (IRRI, 2002).

Statistics analyses

All data were subjected to analysis of variance according to Gomez and Gomez (1984). The statistical analysis was performed using analysis of variance technique by means of "COSTAT" software.

RESULTS AND DISCUSSION

Influence of row ratio of restorer and CMS lines on the yield contributing traits and F0 seed production of SK.2151H hybrid

The effect of row ratio of restorer and CMS lines on seed production of hybrid rice for enhancing the efficiency of seed production, it is necessary to maximize the yield of hybrid seed by improving the out crossing capacity of CMS lines (Shi-Hua *et al.,* 2006; Rahman *et al.,* 2010; Hasan *et al.,* 2015). Different row ratios were significantly influenced on the yield traits (*Fig. 1*).

Flag leaf area (cm^2) was positively influenced by row ratios in the two years (*Fig. 1*). The highest values of flag leaf area of 37.64 and 37.94 cm^2 recorded for the 2:8 row ratios in 2013 and 2014, respectively. The obtained results indicated that the flag leaf area increased with narrow row ratio, comparing to wider row ratio. The results confirmed the findings of Abo-Youssef (2009). Panicle exsertion (%) was significantly influenced by row ratios both the years (*Fig. 1*). The highest values of panicle exsertion (80.38 and 81.38%) were recorded for the 2:8 row ratios in 2013 and 2014, respectively. while, the minimum panicle exsertion was obtained from in 2:12 row ratio. These results indicated that, panicle exsertion (%) increased with narrow row ratio, comparing to wider row ratio. These results were in compliance with those of Abo-Youssef (2003), who observed that the row ratio 2R:8A gave the highest values of 85.23% for panicle exsertion. These results are in accord with (Soumia *et al.,* 2006; Hasan *et al.,* 2010). While, another type of experiment conducted by BRRI and found 2:10 row ratio gave highest seed yield (BRRI, 2008). No. of fertile panicles/hill was highly affected by row ratio in consecutive the two years (*Fig. 1*). The highest number of fertile panicles/hill (19.50 and 20.20) were recorded for the 2:8 row ratio in 2013 and 2014 seasons, but the lowest values (15.75 and 18.85) were recorded for the 2:12 row ratio in 2013 and 2014 seasons, respectively. These results are in accord with Rahman *et al.* (2010), who reported that the row ratio of 2:12 (R:A) achieved the best results. Panicle weight (gm) was positively influenced by row ratios in the two years (*Fig. 1*).

The highest values of panicle weight (2.25 and 2.35 g) were recorded for the 2:8 and the lowest values (2.10 and 2.10) were at 2:12 row ratios in 2013 and 2014 seasons, respectively. These results were agreed with Abo-Youssef (2003), who observed that the row ratio 2R: 8A was achieved the highest values of panicle weight. Panicle length was highly influenced by row ratio in the two years and the highest panicle lengths (24.20 and 24.67 cm) were produced when row ratio was 2:8 in both seasons (*Fig. 1*). The results confirmed the findings of Singh and Singh (1998). Seed set (%) was significantly affected by row ratio and the maximum values of seed set (23.72 and 36.63%) were observed for the 2:8 row ratio in 2013 and 2014, respectively (*Fig. 1*). These results indicated that the percent seed set increased with narrow row ratio, comparing to wider row ratio. The results were agreed with Abo-Youssef (2003). 1000-grain weight (g) was highly influenced by row ratio in the two years and the 2:10 row ratio produced the maximum 1000-grain weight (24.55 and 24.69 g) in 2013 and 2014 seasons, but the lowest values (24.05 and 24.39 g) were recorded at the 2:12 row ratio in 2013 and 2014 seasons, respectively (*Fig. 1*).

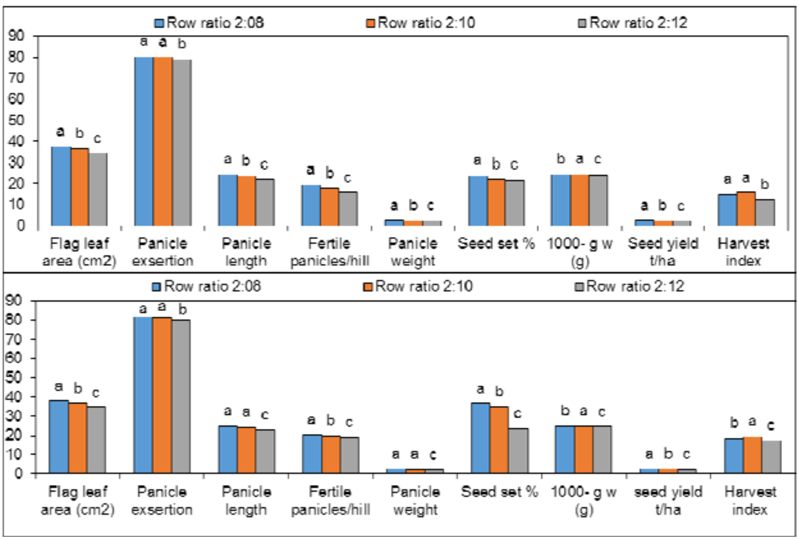

Figure 1 - Effect of row ratios on flag leaf area, panicle exsertion (%), panicle length (cm), No. of fertile panicles/hill, panicle weight, seed set, 1000-grain weight, seed yield and harvest index during 2013 and 2014 .

Evidently, row ratios exhibited differences in seed yield (*Fig. 1*). It was evident that seed yield of both the years were 2.26 and 2.55 t/ha, when row ratio was 2:8. On the other hand, the lowest seed yield (1.98 and 2.22 t/ha) was produced by the ratio of 2:12 in successive years. The row ratio of restorer and CMS lines at 2:12 had the maximum availability of pollen that resulted in the highest grain formation (Rahman *et al.*, 2012). These results were agreed with Virmani (2002). The harvest index was highly influenced by row ratio in the two years (*Fig. 1*). The highest harvest index values (15.81 and 19.30%) were observed at the row ratio of 2:10, but the lowest values (12.43 and 17.25%) were recorded for the 2:12 row ratio in 2013 and 2014 seasons, respectively. This increase in harvest index could be due to the high grain yield.

Mean performance of GA_3 concentrations on the yield contributing traits and F0 seed production of SK.2151H hybrid

Different levels of GA_3 significantly influenced the yield traits of rice (*Fig. 2*). Application the optimum dosages of GA_3 increased the photosynthetic capacity, delay the leaf senescence and promote the rate of rice seed-setting (Zheng *et al.,* 2011; Hasan *et al.,* 2015).

Flag leaf area increased significantly with the increasing GA_3 levels and the highest values were 38.80 and 39.05 cm^2, with the highest levels of GA_3 (400 g), during 2013 and 2014 seasons, respectively (*Fig. 2*). Katta *et al.* (2012) reported that application of GA_3 at the rate of 300 g/ha at first day of heading increased the flag leaf area inside seed production plot.

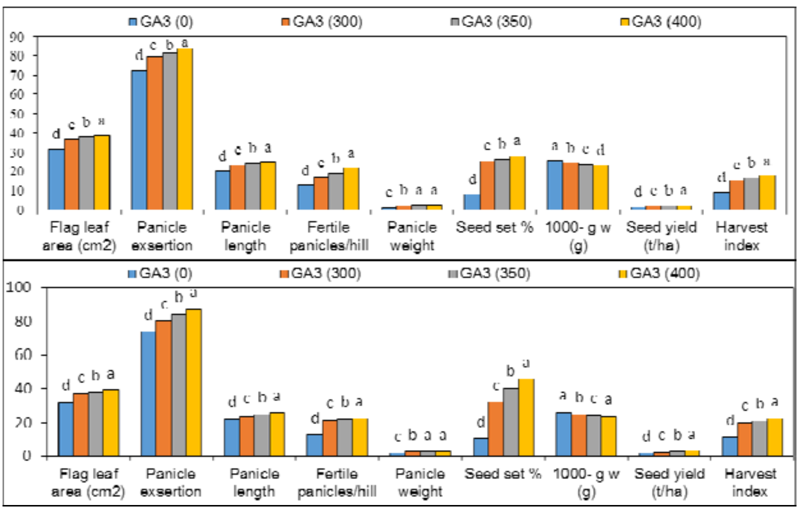

Figure 2 - Effect of GA_3 doses on flag leaf area, panicle exsertion (%), panicle length (cm), No. of fertile panicles/hill, panicle weight, seed set, 1000-grain weight, seed yield and harvest index during 2013 and 2014 .

Biradarpatil and Shekhargouda (2006) found that the application of gibberellic acid (GA_3) at 75 or 25 g/ha significantly enhanced flag leaf area and flag leaf angle. GA_3 significantly influenced the rate of panicle exsertion (%). The highest values of panicle exsertion (83.64 and 87.09%) were recorded at 400 g GA_3 in 2013 and 2014 seasons, respectively (*Fig.*

2). The results were agreed with Hassan *et al.* (2015). Panicle exsertion rate was increased by the increase for GA_3 doses could be associated with stimulating effect of GA_3 for cell division and cell elongation in the plant (Rahman *et al.,* 2012). The result indicated that GA_3 increased panicle exsertion positively improves seed set. Moreover, panicles exsertion increased the chances of seed set because part of the panicle covered with flag leaf might be opened and allowed the cross breeding (Susilawati *et al.,* 2014). Study of Yin *et al.* (2007) have been showed the effect of GA_3 on panicle base elongation of male sterile lines and reported that panicle could be filled out from the flag leaf sheath, so that opportunities of seed formation become larger due to GA_3. Different concentrations of GA_3 had significantly influenced the panicle length. GA_3 at the rate of 400 g produced the highest panicle lengths (24.83 and 25.54 cm) in both seasons, respectively (*Fig. 2*). Similar results were also observed by Tiwari *et al.* (2011) and Susilawati *et al.* (2014). The increased in panicle length might be due to increased activity of cells division, enlargement and elongation for GA_3 that regulates various processes of plant growth and development, which is particularly important in stem elongation. GA_3 applications in high concentrations potentially increased panicle broken because of increase in plant height and panicle, especially during the rainy season (Prasad *et al.,* 1988; Gavino *et al.,* 2008). Therefore, Susilawati *et al.* (2014) reported that GA_3 application must be adapted with responsiveness of male sterile lines, agro-ecological conditions and seasons. The application of different concentrations of GA_3 significantly influenced the number of number of fertile panicles/hill (*Fig. 2*). GA_3 at the rate of 400 g/ha produced 22.00 and 22.46 fertile panicle/hill in 2013 and 2014, respectively. Results indicated that, using GA_3 at proper spraying periods with appropriate dosages was an effective measure for improving the number of number of fertile panicles/hill (*Fig. 2*). These results are in accord with Lei *et al.* (2007). Rahman *et al.* (2012) observed that the progressive improvement in the formation of greater number of fertile panicles/hill might be due to availability of GA_3, which enhanced more tillering and adequacy of GA_3 at 400 g/ha, probably favored the proper cellular activities during panicle formation and development, which led to increase number of effective tillers/hill. A significant variation was found in terms of panicle weight (g), due to the application of different levels of GA_3 (*Fig. 2*). Among the different levels of GA3, the highest panicle weight (g) was found at 400 g GA_3/ha. These results are in accord with Zhu *et al.* (1998), who reported the positive influence of GA_3 on number of grains/panicle. The results showed that GA_3 significantly increased the per cent seed set (*Fig. 2*). The highest values (27.99 and 45.94%) were recorded at 400 g GA_3

in both seasons, respectively. Results indicated that GA_3 played important role increasing the percentages of seed setting. The result of the present study is similar to the findings of Lu *et al.* (2006), who observed that high-seed production was observed by applying GA_3 at the proper time to increase outcrossed seed-setting percentage. Zheng *et al.* (2011) reported that application of (GA_3) could increase the photosynthetic capacity and promote the rate seed-setting. While, Tian and Zhou (1991) reported that the seed set was not directly affected by GA_3 application. GA_3 application greatly influenced the plant height, panicle and spikelet exsertion, stigma exsertion, stigma longevity and receptivity, which might have improved the outcrossing condition and directly affected the seed set (Gavino *et al.,* 2008; Susilawati *et al.,* 2014). 1000-grain weight significantly decreased with increasing the concentrations of GA_3 and the highest 1000-grain weight was observed under control condition (*Fig. 2*). The result of the present study is similar to the findings of Nihal *et al.* (2005). This agrees with Chen (1995), observed that 1000-grain weight was the stable inherited characters in rice variety and were influenced by parents genes. Seed yield increased significantly with the increasing GA_3 (*Fig. 2*).

The highest seed yields of 2.42 and 2.99 t/ha were produced by the application of 400 g GA_3/ha in 2013 and 2014 growing seasons, respectively. While, the control plant produced the lowest seed yield. The decrease in seed yield as found in control could be due to less outcrossing rate and panicle exertion (Rahman *et al.,* 2012). These results are agreement with Sudipta *et al.* (2005), who showed that the angle and duration of spike let opening and out crossing percentage were the main factors in enhancing the seed yield. On the other side, GA_3 applications in high concentrations potentially increased panicle broken because of increase in plant height and panicle, especially during the rainy season (Prasad *et al.,* 1988; Gavino *et al.,* 2008). Concentrations of GA_3 had remarkable increased on the harvest index (HI) with the increasing GA_3 levels the highest HI (17.85 and 22.26%) were observed from the 400 g GA_3 in 2013 and 2014 seasons, respectively (*Fig. 2*). The higher harvest index indicated that GA_3 application accelerated assimilate supply to sink, which is in agreement with the results of Gouping and Etmal (1992). These results indicated that to get highest values of yield characters, a line should be transplanted in eight row and R line in two row with apply 400 g GA_3/ha to obtain highest values of seed yield (2.99 t/ha) and (19%) for harvest index.

Interaction effect between GA_3 and row ratio on different agronomical traits and F0 seed production of SK.2151H hybrid

Based on the results of this study, the interaction between row ratio and GA_3 dose was highly significant for major traits. For flag leaf area (cm^2) was (*Fig. 3*) affected by the interaction between GA_3 400 g/ha and 2:8 row ratio, the best combination to get highest values of flag leaf area (cm^2). The maximum panicle exsertion rate was achieved by the combination of 400 g/ha GA_3 and 2:8 row ratio (*Fig. 4*). So, these results referred to response of GA_3 dose, the highest value was high under narrow row ratio, comparing to wider row ratio, especially for panicle exsertion % for the female IR69625A, which increase the seed set % and subsequently seed yield (t/ha). It was observed that application of GA_3 at 400 g/ha and 2:8 row ratio recorded the highest number of effective panicle/hill (22.73 and 24.00) in 2013 and 2014 seasons, respectively (*Fig. 5*).

In the present research, panicle weight (g) was influenced by the interaction between row ratio and dose of GA_3 and GA_3 (400 g/ha and row ratio 2:8) achieved the highest value in the two seasons, respectively (*Fig. 6*). Panicle length (cm) was affected by the interaction between row ratio and dose of GA_3 and the plants were treated by GA_3 (400 g/ha) and row ratio (2:8) achieved the optimum results and then then increase the seed yield/hill (25.56 and 26.58 cm), during two seasons, respectively (*Fig. 7*).

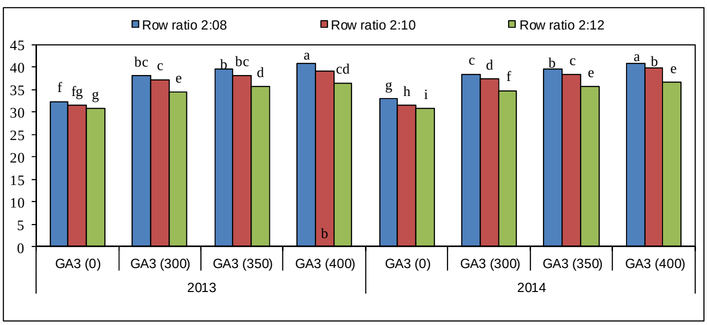

Figure 3 - Flag leaf area (cm^2) as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

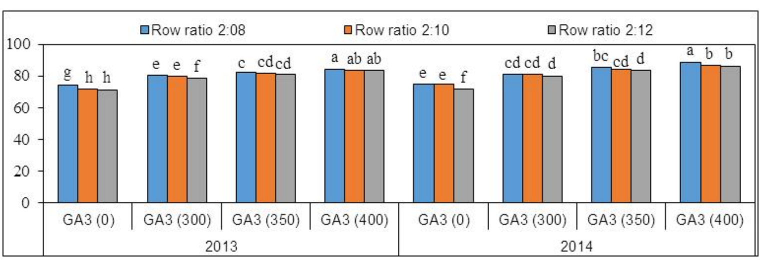

Figure 4 - Panicle exsertion as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

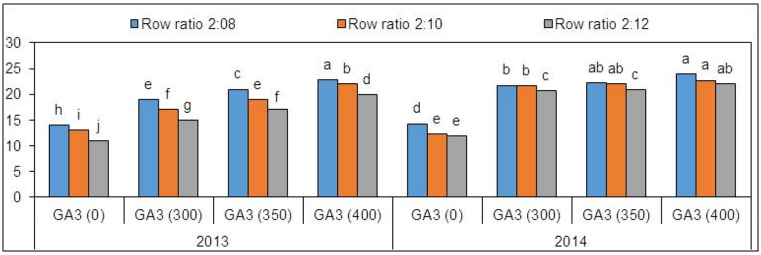

Figure 5 - No. of fertile panicle/hill as affected by the interaction between row ratio and GA$_3$ dose during 2013 and 2014 seasons.

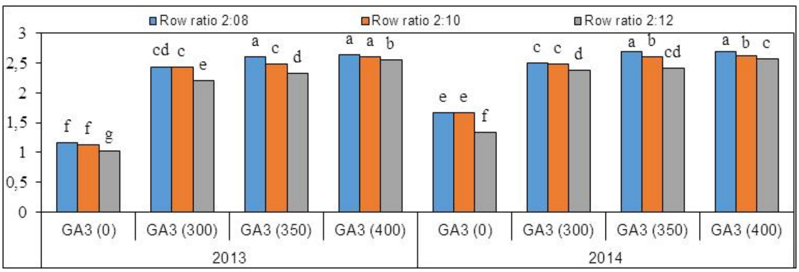

Figure 6 - Panicle weight as affected by the interaction between row ratio and GA$_3$ dose during 2013 and 2014 seasons.

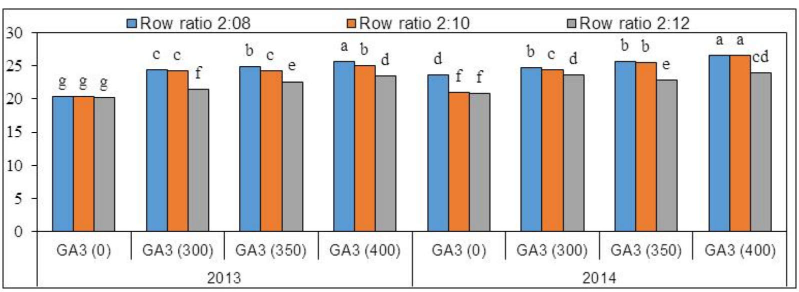

Figure 7 - Panicle length as affected by the interaction between row ratio and GA$_3$ dose during 2013 and 2014 seasons.

Seed setting percentage was influenced significantly with the combination of 400 g/ha GA$_3$ and 2: 8 row ratio in both season (*Fig. 8*). The results in *Fig. 9* revealed that 1000-grain weight was recorded the best results with combination of control (0 g/ha) GA$_3$ and 2:8 row ratio and the results were 26.23 and 26.26 g at two seasons, respectively. These results may be referred to the increase of doses of GA$_3$ could be increase the seed set % and decrease the grain filling rate then the grains will have light weight. Significant differences in seed yield were observed under different row ratios and GA_3 combination (*Fig. 10*).

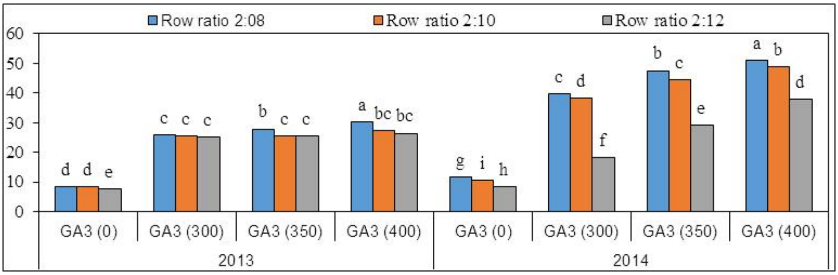

Figure 8 - Seed setting percentage as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

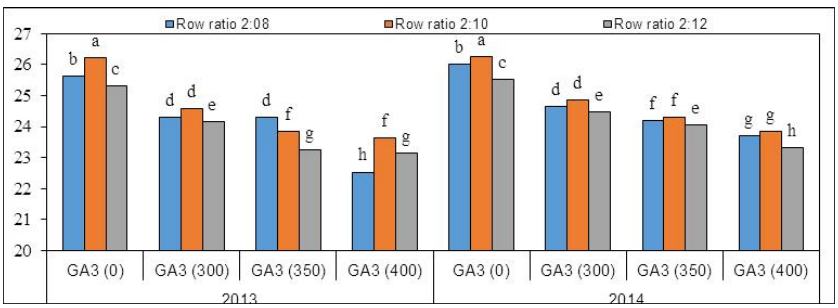

Figure 9 - 1000-grain weight as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

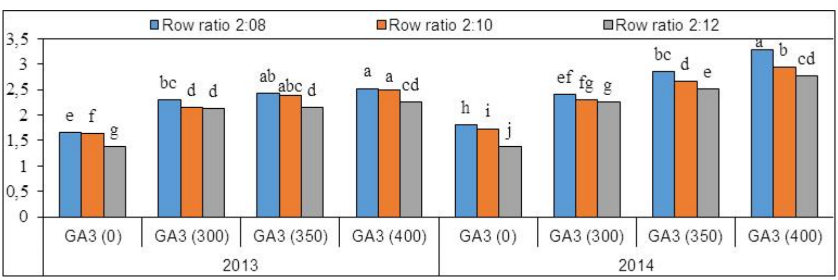

Figure 10 - Grain yield t/ha as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

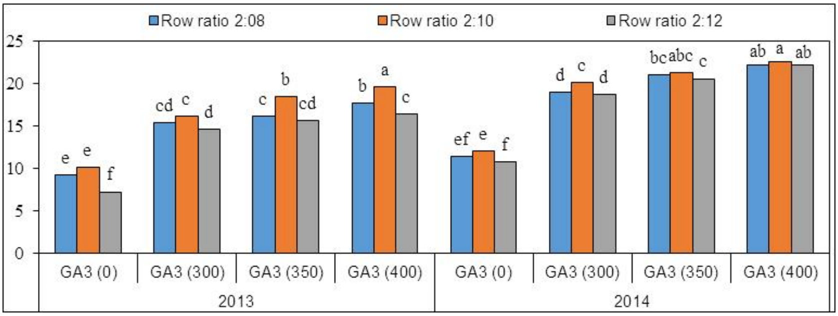

Figure 11 - Harvest index as affected by the interaction between row ratio and GA_3 dose during 2013 and 2014 seasons.

The optimum seed yield was found at 400 g/ha GA_3 combined with 2:8 row ratio in both seasons and the results were 2.52 and 3.28 t/ha in the two seasons, respectively. For harvest index,it was found application of GA_3 (400 g/ha) with combination of row ratio 2:10 was recorded the highest value of harvest index (*Fig. 11*). These results were agreement with Hasan *et al.* (2015). Rahman *et al.* (2012) reported that the highest F1 seed yield was achieved by adding of GA_3 @ 250 g/ha with 2:12 (R: A) row ratio; while, the lowest value was recorded without application of GA_3 (control) at 2:16 row ratio. The combination between row ratio and GA_3 concentrations was significant for grain yield. This increase might be due to the higher outcrossing rate and panicle exsertion (Hamad *et al.,* 2015). These results were agreed with those obtained by Biradarpatil and Shekhargouda (2006), who reported that application of gibberellic acid (GA_3) at 100 ppm, single super phosphate at 1.0%, and KNO_3 at 1.0% to A-line plant at panicle initiation enhanced the 50 % flowering by 3.7, 3.2 and 3.2 days, and increased the hybrid seed yield by 39, 32 and 28%, respectively, over the control.

CONCLUSION

Application of GA_3 and row ratio had significant influence on various traits of hybrid rice. The maximum seed yield was achieved by application of GA_3 @ 400 g/ha. The performance of SK.2151H hybrid of seed yield achieved the best value when row ratio was 2R:8A and the lowest were at the 2:12 row ratio. Maximum net economic return from seed yield was produced by combination of 400 g/ha GA_3 x 2:8 row ratio (R: A).

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