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Effect of Gibberellic Acid on Morphological and Floral Traits, Outcrossing, Seed Yield and Quality in Parental Lines of Hybrid Rice and Efficacy of Ultra Low Volume Sprayer in Economisation of Dose of Gibberellic Acid

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ABSTRACT An investigation was undertaken with two CMS lines, IR58025A and IR62829A with their respective maintainers in split plot design to determine the optimum dose and stage of application of gibberellic acid (GA_3) in parental line seed multiplication plot of hybrid rice. In addition, effect of GA_3 on morphological and floral traits, outcrossing percentage, seed yield and quality with efficacy of ultra low volume (ULV) sprayer in economisation of dose of above chemical was also evaluated. Spraying was done @30, 60, 90, 120 and 150g/ha with knapsack sprayer (KS) and @ 30, 45, 60 and 75g/ha with ULV sprayer at late boot leaf, five per cent panicle exsertion and flowering stage. Results of the study indicated that application of GA_3 @ 120 and 150g/ha with KS and @ 60 and 75g/ha with ULV sprayer were superior and spraying at five per cent panicle exsertion and flowering gave better results than application at late boot leaf stage. There was significant enhancement in plant height, panicle exsertion, floral traits i.e. duration and angle of spikelet opening, stigma exsertion, outcrossing percentage and seed yield with increment of GA_3 dose but had no effect on 100 seed weight and seed quality. The correlation studies indicated that the angle and duration of spikelet opening and outcrossing percentage were the main factors in enhancing the seed yield. The results showed that the yield realized per rupee investment on GA_3 reduced at higher doses. The study highlighted the efficacy of ULV sprayer in economisation of the dose. Although, GA_3 has established its inevitability in hybrid rice seed production but the study emphasized the need of its judicious and timely application at optimum dose for economizing the seed production.

Keywords: Hybrid rice, parental lines, gibberellic acid, morphological and floral traits, outcrossing percentage, seed yield, seed quality, sprayer

Impressive progress made at International Rice Research Institute (IRRI) in breeding parental lines suited to tropical ecologies, optimization of seed production techniques and phenomenal success of hybrid rice in China motivated India to initiate research on hybrid rice technology. Concerted efforts of researchers resulted in release of many public and private sector hybrids. But success and large scale adoption of hybrid rice technology requires development of an efficient and cost effective seed production technology.

Autogamous nature in self pollinated crops like rice restrict outcrossing as their morphological and floral traits are not well suited for cross-pollination [1]. Poor panicle exsertion (25-33% of the spikelets remain enclosed inside flag leaf sheath) of CMS lines is a major problem in hybrid rice seed production (which is associated with physiological mechanism due to the wild abortive cytoplasm) which severely restricts the cross pollination. To overcome this problem, different chemical sprays (GA_3, urea, boric acid, maleic hydrazide) and techniques (flag leaf clipping and agronomic manipulations) have been tried [2-5]. But among these, foliar application of GA_3 was found to be the most effective [5, 7]. In addition, GA_3 is also reported to improve vegetative (plant height, flag leaf angle, panicle exsertion) and floral characters (angle and

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duration of spikelet opening, stigma exsertion and receptivity, anther length and pollen load),number of effective tillers, seed set and yield [2, 5, 6, 7]. GA_3 has proved its effectiveness and inevitability in hybrid rice seed production for obtaining higher seed yield but its high cost is a major constraint in its utilization. In India, Directorate of Rice Research (DRR) has recommended a dose of 45 g/ha to be applied at 5% heading for achieving yields of 1-1.5t/ha but private seed companies are using doses upto 180-225g/ha [8]. Higher doses although yield better but affects the seed quality [4,5]. The adverse effect of preflowering application of GA_3 on seed quality and storability has been documented by several workers [2, 4, 5]. Thus there was a need to optimize the dose, stage of its application with economisation of its use for developing a economically viable seed production technology.

The present investgation was undertaken to determine the optimum dose and stage of application of GA_3 along with efficacy of ultra low volume (ULV) sprayer in economisation of dose of this chemical. In addition, the effect of GA_3 on morphological, floral traits, oucrossing percentage, seed yield and quality was also evaluated.

MATERIALS AND METHODS

Two promising CMS lines and their respective maintainers (IR58025A/B:Experiment 1) and (IR 62829A/B :Experiment 2) were sown at DRR, Hyderabad (winter, 1995) in two different experiments laid out in split plot design with ten main(doses of GA_3), three sub plots(stage of application) and three replications in a row ratio of 6:2 (A:B). In both the experiments, male parents were sown three and five days after sowing female parent in the nursery and later transplanted together with the seed parent for better availability of pollen during flowering. GA_3 was sprayed at 0-150g/ha with an incremental dose of 30g/ha (KS) and 0-75g/ha with an incremental dose of 15g/ha with ULV sprayer. Sprays were given at late boot leaf, 5% panicle emergence and 5% flowering stage. Foliar application of GA_3 was given on consecutive days @ 500 l/ha with 40 per cent of the quantity on the first day and remaining on the second day. Supplementary pollination with the help of bamboo poles was done twice a day in male parents at peak anthesis period. Plant height was measured from base to tip of tallest panicle in a hill. The length of panicle outside flag leaf over total length of panicle was used for assessing panicle emergence. Floral traits were observed on ten randomly selected plants in a plot. Duration and angle of spikelet opening was observed on selected spikelets per panicle. Number of exserted stigma per spikelet in above panicle were counted as extent of stigma exsertion. Number of filled seed per panicle were counted for outcrossing percentage. Seed yield was recorded on plot basis. Seed quality was assessed by germination and viability. Seeds were placed between paper at 30°C and counts were recorded on fourth (first) and seventh(final) day [9]. Viability test was carried out as per Kittock and Law [10].

RESULTS AND DISCUSSION

Plant height and panicle exsertion

Plant height of CMS and maintainer line in hybrid seed production is documented to have important bearing on outcrossing rate and seed yield. Application of GA_3 significantly increased the plant height and panicle exsertion of both CMS and maintainer lines but the effect was more evident on the former (CMS lines). The height increased from 62.5(control) to 81.2cm and 58.3(control) to 75.1cm respectively in IR58025A and IR62829A with 120 g/ha and 150 g/ha GA_3 respectively applied with KS and to 81.8 and 67.8 cm respectively in above lines with 75g/ha GA_3 applied with ULV sprayer (Table 1). Panicle exsertion increased to 84.2 and 85.3%(150g/ha-KS) and 81.7 and 81.9% (75g/ha-ULVS) respectively over control in IR58025A and IR62829A (Table 1).The increase in plant height and panicle exsertion with foliar application of GA_3 could be attributed to the elongation of internodal cells [11] especially the three uppermost internodes resulting in dropping of the flag leaf to an angle allowing better panicle exsertion. Thus, the differential plant height of A and B lines maintained with the application of GA_3 helped in enhancing the pollen dispersal by wind and gravity. Results are in accordance with Duan and Ma [2] and Pandey [5].

Floral traits

In hybrid seed production of rice transfer of pollen from pollinator to seed parent is crucial to attain higher seed set in CMS lines.Rice being an autogamous crop,is not very well suited to outcrossing but floral traits like stigma exsertion, angle and duration of spikelet opening aid in increasing outcrossing [12, 13]. For successful hybrid seed production, sufficient pollen must be lodged on receptive stigma lobes of each spikelet and under favourable weather conditions CMS parents require half an hour for depositing two or more pollen grains on stigma lobes of more than 80% of the spikelets.

Table 1. Effect of GA_3 application on morphological and floral traits of parental lines of hybrid rice

GA_3 Dose (g/ha) and Sprayer	Plant Height (cm)				Panicle exsertion (%)		Duration of spikelet opening (min)		Angle of spikelet opening (°)		Stigma exsertion (%)	
	IR58025A	IR58025B	IR62829A	IR62829B	IR58025A	IR62829A	IR58025A	IR62829A	IR58025A	IR62829A	IR58025A	IR62829A
Treatments												
Control	62.5	76.3	58.3	64.3	56.0 (48.4)	59.5 (50.4)	120.5	107.0	29.4	28.5	1.07 (5.74)	1.03 (5.74)
30 KS	69.8	77.7	59.7	66.4	64.4 (53.3)	65.0 (53.7)	132.5	128.0	33.3	30.7	1.23 (6.29)	1.20 (6.29)
60 KS	72.8	83.4	68.6	72.1	69.9 (56.7)	70.3 (56.9)	136.0	132.0	36.2	35.0	1.35 (6.55)	1.27 (6.29)
90 KS	77.1	88.1	71.0	74.2	75.4 (60.2)	73.9 (59.2)	140.0	139.0	38.0	37.7	1.40 (6.80)	1.46 (6.80)
120 KS	81.2	90.8	73.5	76.1	82.6 (65.3)	80.4 (63.7)	146.1	140.1	42.9	41.9	1.48 (6.81)	1.49 (6.81)
150 KS	81.0	89.9	75.1	75.6	84.2 (66.5)	85.3 (67.4)	155.2	153.0	44.9	44.9	1.57 (7.04)	1.57 (7.04)
30 ULVS	73.7	83.9	59.6	64.3	66.1 (54.3)	71.5 (57.7)	127.0	128.3	33.5	34.4	1.28 (6.20)	1.31 (6.55)
45 ULVS	74.6	84.0	63.6	66.0	73.0 (58.6)	74.8 (59.8)	142.0	135.0	37.5	35.9	1.37 (6.55)	1.34 (6.55)
60 ULVS	78.4	86.2	61.6	67.9	77.8 (61.8)	81.0 (64.1)	143.0	139.1	37.6	36.9	1.41 (6.80)	1.38 (6.55)
75 ULVS	81.8	84.3	67.8	69.9	81.7 (64.6)	81.9 (64.8)	141.2	142.0	39.8	40.4	1.48 (6.81)	1.46 (6.81)
SE±	2.1	2.4	1.8	1.1	1.1	1.6	0.8	1.2	1.3	2.2	0.04-	0.03
CD(0.05)	4.4	5.1	3.7	1.2	2.3 (8.7)	3.4 (10.6)	1.7	2.3	2.7	4.6	0.08	0.06
Stage of application												
Late boot leaf	76.6	83.1	63.1	67.1	70.3 (56.9)	72.1 (58.1)	137.0	131.0	36.4	34.3	1.35 (6.55)	1.33 (6.55)
5% panicle exsertion	75.5	84.1	65.6	67.7	76.3 (60.8)	76.6 (61.0)	140.0	136.5	38.6	38.1	1.44 (6.81)	1.36 (6.55)
5% flowering	74.0	85.6	69.0	74.0	72.7 (59.5)	74.3 (59.5)	138.0	135.2	36.9	37.5	1.30 (6.55)	1.36 (6.55)
SE±	1.2	1.1	0.8	0.7	0.7	1.3	0.6	0.5	1.0	1.0	0.02	0.02
CD (0.05)	NS	NS	1.7	1.5	(7.04)	(9.28)	1.2	1.1	NS	2.0	(0.05)	NS

Values in parentheses indicate arc sine values

Wide opening of the glumes for longer duration in female parent enables better interception of air borne pollen by stigma [14]. In the present study, foliar application of GA_3 significantly influenced the above floral traits. Duration of spikelet opening is reported to range between 105-280 min in different CMS lines [15]. In our study, it ranged from 120-155 min and 107-153 min in IR 58025A and IR62829A respectively. The duration of spikelets opening increased by 34.7 and 46.0 min respectively in IR58025A and IR62829A over control with foliar spray @150g/ha GA_3(KS) (Table 1). GA_3 was also effective in enhancing the angle of spikelet opening and stigma exsertion.With the incremental dose of GA_3,there was a linear increase in spikelet opening angle (in both the CMS lines), which increased by 15.5 and 16.4° respectively in IR58025A and IR62829A over control (Table 1). In the study, stigma exsertion in CMS lines also increased upto 1.57 % with 150g/ha GA_3 as compared to control (1.03-1.07%). The results are in accordance with Sharma [17].

Flowering behaviour is reported to be greatly influenced by weather conditions. The extent of seed set on CMS lines is also influenced by weather conditions besides, synchronisation of flowering and duration of anthesis. Climatic factors plays a major role in altering floral biology of rice plant. Environmental factors that influence natural outcrossing in rice includes, temperature, relative humidity, light intensity and wind velocity. A temperature and RH range of 20-30°C and 75-90% respectively with mild wind during flowering was found to be ideal. In the present study, favourable weather conditions prevailed during flowering i.e. temperature (22.8-37.0°C), RH(29.8-73.7%),wind velocity(4km/h) with bright sunshine and no rainfall which helped in better crop performance and outcrossing.

Outcrossing percentage, seed yield and quality

Hybrid seed production largely depends on potential outcrossing which in turn is influenced by pollen quantity, stigma receptivity, floral structure and environment conditions. In the present study, outcrossing percentage increased linearly with increase in concentration of GA_3 application and nearly doubled (38-41%) with 150 g/ha GA_3 as compared to control(19-20 %) (Table 2). Increased outcrossing percentage favoured higher seed yield. In the present study, seed yield increased by 33 and 49% respectively (150g/ha GA_3:KS) over control in the CMS lines; IR58025A and IR62829A (Table 2) but the maintainer lines failed to respond to the sprays. GA_3 spray also had no influence on 100 seed weight of the parental lines and the interaction effects were not significant for all the traits studied.Superiority of higher doses of GA_3 on seed yield of CMS parents may be attributed to perfect synchronization of flowering of parental lines, improved panicle exsertion, floral traits, outcrossing percentage, supplementary pollination by bamboo twice a day during peak anthesis, better environmental conditions prevailing during flowering. Our results are in confirmation with Virmani [18], Prabagarana & Ponnuswamy [19] and Kalavathi *et al.* [3].

The foliar application of GA_3 showed no reduction in germination and viability of seeds produced (Table 2). Germination ranged above 97% in freshly harvested seeds of both the genotypes.Duan and Ma [2] also reported that preflowering GA_3 application to CMS lines although resulted in decline in quality and storability but freshly harvested seeds had high germination (above 84%).

Correlation studies

Correlation studies indicated a significant positive correlation of seed yield with floral traits and outcrossing percentage (Table 3). Kato and Namai [13] reported that the stigma exsertion percentage is reported to be positively correlated with floral characteristics such as large pistil, stigma and angle between lemma and palea.In addition, the percentage of spikelets with protruding stigmas and angle of spikelet opening were positively associated with seed set and natural outcrossing respectively. The multiple regression equation of yield with other traits indicated that yield is highly dependent on outcrossing, spikelet angle and duration of opening and panicle exsertion.

Economics of GA_3 application

The yield realized per rupee invested on GA_3 decreased consistently with increase in the dose of this growth regulator. At lower doses (30g/ha), the additional yield realized was 0.63 kg/ha over control while it was as low as 0.13 kg/ha at higher doses (150g/ha).Since the yield realized in both the CMS were not commensurating at higher doses the results emphasized the need of its judicious use.

Optimum dose and stage of application

Chinese have recommended higher doses of 150-225g/ha at pre emergence stage [2] whereas Virmani *et al.* [12] recommended application @90-100g/ha at 10-15 per cent boot leaf stage.

Table 2. Effect of GA_3 application on outcrossing, seed yield and quality of the parental lines of hybrid rice

GA_3 Dose (g/ha) and Sprayer	Outcrossing (%)		Seed yield (q/ha)				Germination(%)	
	IR58025A	IR62829A	IR58025A	IR58025B	IR62829A	IR62829B	IR58025A	IR62829A
Treatments								
Control	20.12 (26.6)	18.91 (25.7)	10.9	23.5	9.97	22.3	99.8 (87.4)	99.3 (85.7)
30 KS	26.3 (30.8)	24.2 (29.4)	11.3	24.1	10.81	22.8	99.0 (84.2)	98.8 (83.5)
60 KS	30.4 (33.0)	29.3 (32.7)	12.4	24.3	11.44	23.1	98.5 (82.9)	98.4 (82.7)
90 KS	33.0 (35.0)	33.1 (35.1)	13.4	24.3	13.27	23.2	98.4 (82.7)	98.0 (82.0)
120 KS	36.5 (37.1)	36.5 (37.1)	14.8	24.4	13.6	23.4	98.3 (82.5)	97.8 (83.4)
150 KS	40.9 (39.7)	38.3 (38.2)	14.6	24.9	14.9	23.4	97.8 (81.4)	98.0 (82.0)
30 ULVS	28.0 (31.9)	24.6 (29.7)	11.8	24.2	10.6	23.1	98.7 (83.4)	98.8 (83.5)
45 ULVS	33.2 (35.1)	29.2 (32.7)	12.9	24.2	11.8	23.2	98.4 (82.7)	98.6 (83.2)
60 ULVS	35.6 (36.6)	32.4 (34.7)	14.4	24.4	12.7	23.3	98.4 (82.7)	98.5 (82.9)
75 ULVS	40.0 (39.5)	36.0 (36.8)	14.7	24.5	13.9	23.4	98.1 (82.0)	98.3 (82.5)
SE±	1.69	1.4	0.7	0.69	0.9	0.8	0.2	0.3
CD(0.05)	3.56 (10.7)	2.96 (9.8)	1.56	NS	2.0	NS	NS	NS
Stage of application								
Late boot leaf	27.1 (31.3)	27.26 (31.4)	11.7	24.2	11.6	23.0	98.6 (83.2)	98.8 (83.5)
5% panicle exsertion	37.2 (37.5)	34.0 (35.6)	14.7	24.4	13.1	23.2	98.5 (82.7)	98.6 (83.2)
5% flowering	32.9 (35.0)	29.6 (32.9)	13.0	24.3	12.2	23.1	98.5 (82.9)	97.6 (81.3)
SE±	0.65	1.0	0.4	0.38	0.4	0.4	0.1	0.2
CD (0.05)	(6.5)	(8.3)	0.8	NS	0.8	NS	NS	NS

Table 3. Correlation between seed yield and different morphological and floral traits

Characters		Correlation coefficient	
		IR58025A	IR62829A
Yield			
	Plant Height–CMS line	0.49	0.59
	Maintainer line	0.56	0.41
	Duration of spikelet opening	0.65**	0.84**
	Angle of spikelet opening	0.68*	0.88*
	Outcrossing	0.84**	0.90**
Outcrossing			
	Plant Height–CMS line	0.57	0.70*
	Maintainer line	0.64*	0.39
	Duration of spikelet opening	0.78**	0.82**
	Angle of spikelet opening	0.79**	0.84**

* P<0.05 ** P<0.01

Recommended doses of 45-50g/ha with KS and 25g/ha with ULV have given positive response at DRR[8]. In this investigation results indicated that 120 and 150g/ha with KS and 60-75g/ha with ULV (Table 1-2) sprayer gave better results than other treatments.

Higher values of morphological and floral traits,panicle exsertion, seed set and seed yield were observed when spraying was done at five per cent panicle emergence and flowering stage (Table 1 and 2). Hence ideal stage identified for GA_3 application was, 5% panicle emergence and flowering as application before or after critical stages had limited role in altering above traits. The results are in confirmation with Sharma [17].

Economisation of dose through ULV sprayer

GA_3 has proved its effectiveness and inevitability in hybrid rice seed production for obtaining higher seed yield but its high cost is a major constraint in its utilization. Results indicated that ULV sprayer could greatly increase the efficacy of GA_3 application as a lower dose of 60-75g/ha gave similar yields as that with 120-150g/ha sprayed through KS (Table 1-3). This significant decrease in dosage may be due to higher and more uniform distribution of GA_3 solution by ULV sprayer. Results are in accordance with Anonymous [8].

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