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Influence of varietal and plant growth regulators on the growth and yield of ratoon rice

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Abstract
At the Agricultural College and Research Institute in Killikulam, an experiment trial was run during the *Pishanam* and *Early kar* seasons of 2021–2022. Treatments with various plant growth regulators were applied over different varieties of rice in respective randomized plots. This Experimental study suggests that application plant growth regulators significantly enhance the yield of ratoon rice. In that GA@ 5ppm gives the higher DMP and ratoon rice yield with higher B:C ratio in ASD16 followed by CR1009 perform well with this same treatment. Similar trend also found in straw yield. Followed by N: P: K (19:19:19) @1%+ NAA@ 40ppm gives the better grain and straw yield in both ASD16 and CR1009. BA@ 100ppm highly influences the tiller production, plant height and regeneration rate of buds but not much influence the grain and straw yield. White ponni mutant 22-2 performs poorly with all treatments.

Keywords: Varieties, plant growth regulators, growth, yield of ratoon rice

1. Introduction
Rice (*Oryza sativa* L.) is semi- aquatic grass and most widely produced food grain crop in tropical and subtropical areas of the world especially in Asia. Rice cultivation has long played an important part in the global food crisis that may be grown using a variety of techniques. In world, India is the second largest rice producer after China. Rice transplanting is the most common and traditional technique of establishment in irrigated lowland circumstances. Indian farmers mostly followed the rice- wheat based cropping system. In that most of the farmers following the rice mono cropping or rice fallow pulses. No one go for rice ratooning like sugarcane due to the lacking of consistency in scientific studies in India. The rice ratooning method is one of the best management practices for obtaining a second rice yield from budding tillers from prior stubbles after the rice crop has been harvested in rice cropping systems. Ratooning is the process of regenerating new tillers from the rice stubbles of a previously harvested rice crop (Harrell *et al.*, 2009) [6]. Ratoons have several advantages, including increased rice productivity and efficiency in terms of time, labour and cost (Pasaribu *et al.*, 2018) [11]. It's also a greener system than single- and double-season rice systems, contributing less to global warming (Firouzi *et al.*, 2018) [5] and (Yuan *et al.*, 2019) [17]. In tropical area of Asia have roughly 30% of rice area under the ratoon rice. This was nearly about 26.43 million hectares. Ratoon rice is also a long-term technical system that contributes significantly to total rice production (Lin *et al.*, 2015). Ratooning offers an occasion to get an increased productivity with low cost especially in summer season and also increase the cropping intensity per unit area by shorter growth duration nearly 50 % than main crop. There are various hidden benefits to using the ratooning system over other methods, including no land preparation and planting expenditures (Zandstra *et al.*, 1979) [18], improved water use efficiency, economical machinery use (Prashar, 1970) [12], and significant time savings during the crop growing phase (Mahiul Haque *et al.*, 1980) [9]. In India farmers mostly won't go for ratoon rice due to lack of awareness and suitable varieties for ratooning but United states and China doing ratoon cultivation in large scale with higher yield potential by innovating new ratoon cultivars. China is now creating a number of mature ratoon rice cultivars with consistent and large grain yields (Li *et al.*, 2009, Xu *et al.*, 2015).

Use of growth promoting substance in appropriate rice cultivar will helps in increase the regeneration rate, bud production, tiller production, panicle length, maximum seed set, grain yield and straw yield in ratoon condition. Hence this experiment was conducted to find out the influence of plant growth regulator and varietal performance of ratoon rice suitable for Tamil Nadu Tamirabarani command area.

2. Materials and method

2.1. Location of the experimental site

In the southern region of Tamil Nadu, at the Agricultural College and Research Institute in Killikulam, was the experimental field was situated. The experiment was conducted in field No. 37a (B-block) of the college's research farm during the *pishanam* (main crop) and *early kar* season (ratoon crop). This field is located at an altitude of 40m above mean sea level and is geographically located at 8^0 46' N latitude and 77^0 42' E longitude. It is also designated under the East Coast Plains and Hills of the Indian agroclimatic zone.

2.2. Experimental design and layout

The experiment was positioned in Randomized Block Design (RBD) with twelve treatments and replicated thrice. Treatments with different combinations of plant growth regulators were applied in different varieties of rice in respective randomized plots. The layout was formed based on duration of crop, plant spacing necessities with definite dimensions for irrigation channels and plots.

In this experiment have different plant growth regulators *viz*., Benzyladenosine, Gibberellic acid, Naphthalene Acetic Acid, Indole Acetic Acid and N:P: K (19:19:19) with various concentration of 100ppm, 5 ppm, 40 ppm, 40 ppm and 1%, respectively applied. The treatments consist of T_1- ASD16 + BA 100 ppm, T_2- White Ponni mutant (22-2) + BA 100 ppm, T_3- CR1009+ BA 100 ppm, T_4- ASD-16+ GA 5 ppm, T_5- White Ponni mutant (22-2) + GA 5ppm, T_6- CR1009 + GA 5 ppm, T_7- ASD16 + IAA 40 ppm, T_8- White Ponni mutant (22-2) + IAA 40 ppm, T_9- CR1009 + IAA 40ppm, T_{10}-ASD16 + ALL -19 +NAA 40 ppm, T_{11}- White Ponni mutant (22-2) + ALL -19 + NAA 40 ppm, T_{12} - CR1009 + ALL -19 + NAA 40 ppm. The plant growth regulators *viz*., BA@ 100 ppm, GA @ 5 ppm, IAA @ 40 ppm and NAA@ 40 ppm + N: P: K (19:19:19) were applied at 3 DAH, 15 DAH, 10 DAH and 10 DAH, respectively.

2.3. Data Collection

2.3.1. Growth attributes

In ratoon rice, growth parameters like plant height (cm), dry matter production (kg ha^{-1}), total number of tillers $hill^{-1}$ are observed and statistically analysed.

2.3.1a. Plant height

Observation was taken at 30 days after harvest, 60 days after harvest and before harvest. Therefore, average height of plant was measured for each hill from base of the plant culm to tallest leaf present in the hill and it was expressed in cm.

2.3.1b. Dry matter production (kg ha^{-1})

DMP was recorded at 30 DAH, 60 DAH and at harvest (kg/ha). Plant was first sun dried, then oven dried at 65 ^{0}c for 48 hrs until get constant weight. The weight was recorded.

2.3.1c. Total tillers hill $^{-1}$

Total number of tillers was counted at 30 DAH, 60 DAH and before harvest of ratoon rice. Here all productive and un productive tillers are counted.

2.3.2. Yield attributes

Yield parameters like grain yield, straw yield and harvest index were estimated.

2.3.2a. Grain yield (kg ha^{-1})

From plot area, every net plot was harvested and dried at 14% moisture. Then grain yield was recorded and expressed as kg/ ha.

2.3.2b. Straw yield (kg ha^{-1})

Grains are separated by threshing after harvest. Then straw yield was recorded for all plots after drying and expressed as kg/ ha.

2.3.2c. Harvest index

Harvest index was calculated by using the following formula.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

4.1. Result and Discussion

4.1a. Plant height

Effect of plant growth regulators on plant height at various growth stages of ratoon rice was given in the Table1. Maximum plant height was recorded 63.7 cm at 30 DAH, 74.1 cm at 60 DAH and 84.3 cm at harvest stage of ratoon rice of ASD16 with the application of BA 100 ppm @ 3DAH. It was on par with CR1009 with BA 100 ppm application. This results was confirmed with Anandhakrishnaveni *et al.*, 2002 [2], triacontanol and benzyl adenine (BA) had a good effect on node and internode elongation, leaf metrics such as leaf area index (LAI), leaf area duration (LAD) and chlorophyll concentration (Chl) in rice leaves. Followed by spraying of GA @ 5ppm increased the plant height of 58.7cm at 30 DAH, 69.9cm at 60 DAH and 79.9cm at harvest stage was recorded in CR1009. Singh *et al.* (2019) [16] showed the same like results. GA3 at 50 ppm produced the highest plant height, number of leaves, and number of nodes per plant on okra, according to (Ravat *et al.*, 2015) [13]. Application of IAA @ 40 ppm has not much influence on the plant height in irrespective of varieties.

Table 1: Effect of plant growth regulators on plant height at various growth stages of rice

	Treatment details	30 DAH	60 DAH	At harvest
T1	ASD-16+ BA 100 ppm	63.7	74.1	84.3
T2	White ponni mutant 22-2+ BA 100 ppm	45.9	54.2	66.1
T3	CR1009+ BA 100 ppm	60.2	71.1	86.9
T4	ASD-16+ GA 5 ppm	57.4	66.6	78.0
T5	White ponni mutant 22-2+ GA 5ppm	45.5	52.5	59.1
T6	CR1009+ GA 5 ppm	58.7	69.9	79.9
T7	ASD-16+ IAA	48.8	55.9	61.7
T8	White ponni mutant 22-2+ IAA	44.2	47.4	57.6
T9	CR1009+ IAA	45.9	52.1	60.0
T10	ASD-16+ ALL -19 +NAA 40 ppm	50.8	57.1	66.0
T11	White ponni mutant 22-2+ ALL -19 +NAA 40 ppm	45.1	51.6	59.0
T12	CR1009+ ALL -19 +NAA 40 ppm	53.7	60.2	66.4
SEd		6.4	6.5	7.0
CD (p= 0.05)		13.3	13.5	14.6

4.1b. Dry matter production

Effect of varieties and plant growth regulators on DMP (kg ha^{-1}) of ratoon rice given in Table 2. Maximum DMP was recorded with the application of GA @ 5 ppm in ASD16, 1652kg/ha at 30 DAH of main crop, 6540 kg ha^{-1} at 60 DAH and 10145 kg ha^{-1} at harvesting stage. This was on par with GA @ 5 ppm application in CR1009. This result was confirmed with that finding of (Moon *et al.*, 2003) who used GA3 at 0, 25, 50, and 100 ppm in Satsuma mandarin and found that the number of blossoms was significantly reduced but the number of vegetative shoots was significantly enhanced. According to Sharma *et al.*, 2008, applying GA3 at a concentration of 10 ppm to plum trees promoted tree growth, improved fruit weight and volume, and boosted yield. Followed by higher DMP was recorded in application of N: P: K (19:19:19) @ 1%+ NAA@ 40 ppm in ASD16. This was on par with CR1009 + N: P: K (19:19:19) @ 1 % + NAA 40ppm. Foliar spray of NAA treatment might be increased DMP due to enhanced internal physiology of growing fruit in terms of better availability of water, nutrients, and other chemicals necessary for healthy growth, resulting in increased size. This was reported by Jain *et al.*, 2010. In the application of 19:19:19 (NPK) 2 per cent spray at flowering (60 DAS) the highest root length and dry matter production were recorded due to increasing of leaf area, number of branches per plant and photosynthetic efficiency by Kumar *et al.*, 2018 [7]. On an average value, lower rice ratoon DMP was recorded in White ponni mutant 22-2 under all the three plant growth regulators applied. Moreover, IAA @ 40 ppm application has not much influence on the plant DMP in irrespective of varieties.

Table 2: Effect of varieties and plant growth regulators on DMP (kg ha^{-1}) of ratoon rice

Treatment details		30 DAH	60 DAH	At harvest
T1	ASD-16+ BA 100 ppm	893	4684	7698
T2	White ponni mutant 22-2+ BA 100 ppm	713	3169	5680
T3	CR1009+ BA 100 ppm	872	4205	7138
T4	ASD-16+ GA 5 ppm	1652	6540	10145
T5	White ponni mutant 22-2+ GA 5ppm	1024	4569	8399
T6	CR1009+ GA 5 ppm	1559	5898	9798
T7	ASD-16+ IAA	956	5489	8529
T8	White ponni mutant 22-2+ IAA	791	3897	7172
T9	CR1009+ IAA	935	4654	8305
T10	ASD-16+ ALL -19 +NAA 40 ppm	1163	5863	8907
T11	White ponni mutant 22-2+ ALL -19 +NAA 40 ppm	904	4100	7413
T12	CR1009+ ALL -19 +NAA 40 ppm	1012	5108	8845
SEd		82.7	388.3	533.8
CD (p= 0.05)		179.5	842.7	1201.9

4.1c. Total tillers hill $^{-1}$

Effect of varieties and plant growth regulators on total number of tillers hill $^{-1}$ of ratoon rice was given in the Table 3. Higher tiller number was observed with the application of BA @ 100 ppm in ASD16, produced 30 tillers at 30 DAH, 33 number of tillers @ 60 DAH, 36.4 tillers at harvesting stage. This was on par with CR1009 coupled with BA @ 100 ppm. The result was confirmed with Li *et al.*, 2002 and stated that endogenous cytokinin (iPA) level in the mother stem 19 days after complete heading in the main rice crop was observed to increase axillary bud formation, it leads to form multiple shoots from single nodes. (Raza *et al.*, 2017) [14] reported that 67 mg/L BA in soybean increase adventitious shoots with a 50- 100 per cent regeneration rate. Among the treatments, minimum number of tillers were recorded with the application of IAA 40 ppm in white ponni mutant 22-2.

Table 3: Effect of varieties and plant growth regulators on total number of tillers hill $^{-1}$ of ratoon rice

Treatment details		30 DAH	60 DAH	At harvest
T1	ASD-16+ BA 100 ppm	30	33	36.44
T2	White ponni mutant 22-2+ BA 100 ppm	15.8	21	24
T3	CR1009+ BA 100 ppm	26.5	30.89	34.6
T4	ASD-16+ GA 5 ppm	25.4	28.5	31.5
T5	White ponni mutant 22-2+ GA 5ppm	14.6	18.9	19.3
T6	CR1009+ GA 5 ppm	24.3	27.2	28.3
T7	ASD-16+ IAA	20.8	23.3	25.22
T8	White ponni mutant 22-2+ IAA	10.8	12.6	13.1
T9	CR1009+ IAA	20.3	23.7	24.33
T10	ASD-16+ ALL -19 +NAA 40 ppm	23.5	26.3	29.89
T11	White ponni mutant 22-2+ ALL -19 +NAA 40 ppm	12.6	15.17	16.66
T12	CR1009+ ALL -19 +NAA 40 ppm	22.1	25.6	25.33
SEd		1.4	1.5	1.6
CD (p= 0.05)		3.0	3.2	3.4

4.1d. Grain yield (kg/ha)

Effect of varieties and plant growth regulators on grain yield kg/ha of ratoon rice given in the Table 4. The maximum increase on grain yield at 4615 kg ha $^{-1}$ was recorded with the spraying of GA @ 5 ppm in ASD16, however it was on par with CR1009 along with GA @ 5ppm applied at 15 DAH produced 4378 kg ha^{-1} followed by spraying of N: P: K (19:19:19) @ 1% + NAA @40 ppm recorded next higher yield of 4052 kg ha^{-1} in ASD16. Gibberellins regulate fruit development in a variety of ways and at various stages. Fruit development is a complicated and well-controlled process. Growing fruits have a high metabolic rate and operate as significant nutrient sinks, with hormones perhaps influencing the process (Brenner *et al.*, 1995). The result is in accordance the findings of Zhang *et al*. (2004), 25 days after the complete heading stage of the main rice crop and three days after harvesting, applied gibberellin 920 and cytokinin, boosting extra yields by 669 and 269 kg ha^{-1} correspondingly. Lower yield 2560 kg ha^{-1} was recorded in white ponni mutant 22-2 with the spraying of BA @ 100 ppm. BA 100 ppm does not have the influence on grain yield of the all these varieties.

4.1e. Straw yield (kg/ha)

Effect of varieties and plant growth regulators on straw yield kg/ha of ratoon rice given in the Table 4. The higher straw yield of 5215 kg ha^{-1} was obtained in ASD16 with the application of GA @ 5 ppm and it was on par with CR1009 + GA @ 5ppm followed by application of N: P: K (19:19:19) 1% + NAA @ 40 ppm significantly influence the yield. The higher straw yield in these treatments might be due to the PGRs can improve seedling emergence to enhance nutrient uptake and allocation within the plant, keep improving photosynthesis, partitioning, and better translocation of photo-assimilates, and affect crop performance by modifying the source–sink balance and changing plant responses to all development related factors affecting plant growth from embryo stage to crop maturity (Amanullah *et al.*, 2010) [1]. Similar findings was also found by (Chindi *et al.*, 2019) [4] GA causes plants to grow longer stems and accumulate more dry matter. Lowest straw yield of 2995 $kgha^{-1}$ was recorded in spraying of BA @ 100ppm. In initial stages BA enhances the plant height and tillers regeneration however at the later part of reproductive stage the BA was not much effective and hence the dry matter accumulation was reduced in these treatments.

4.1f. Harvest index

Effect of varieties and plant growth regulators on harvest index of ratoon rice given in the Table 4. Harvest index not much influenced by variety and plant growth regulators. Harvest index was ranged from 0.45 to 0.47. However maximum harvest index was obtained in ASD16 with the application of GA@ 5ppm than other treatments.

Table 4: Effect of varieties and plant growth regulators on grain yield, straw yield and harvest index of ratoon rice

Treatment details		**Grain yield** (kg ha^{-1})	**Straw yield** (kg ha^{-1})	**Harvest index**
T1	ASD-16+ BA 100 ppm	3550	4012	0.47
T2	White ponni mutant 22-2+ BA 100 ppm	2560	2995	0.46
T3	CR1009+ BA 100 ppm	3129	3786	0.45
T4	ASD-16+ GA 5 ppm	4615	5215	0.47
T5	White ponni mutant 22-2+ GA 5ppm	3782	4387	0.46
T6	CR1009+ GA 5 ppm	4378	5072	0.46
T7	ASD-16+ IAA	3912	4381	0.47
T8	White ponni mutant 22-2+ IAA	3215	3794	0.46
T9	CR1009+ IAA	3652	4398	0.45
T10	ASD-16+ ALL -19 +NAA 40 ppm	4052	4579	0.47
T11	White ponni mutant 22-2+ ALL -19 +NAA 40 ppm	3312	3908	0.46
T12	CR1009+ ALL -19 +NAA 40 ppm	3953	4671	0.46
SEd		229	377	
CD (p= 0.05)		475	783	

5. Conclusion

Due to increasing population, we are in the situation to intensify crop production in future. Sustainable intensification of conventional agricultural systems is essential for upscaling production and ensuring the country's food security. Rice fallow (14 million hectares) is a typical monocrop rice-based system of South Asia (especially India), and it is currently garnering more attention as a possible way of sustainable intensification. In most of the rice-rice cropping system, cultivation of a second crop becomes difficult due to failure of monsoon rainfall and decrement of water table in the underground aquifer and reservoirs. Under such circumstances, traditional practice of ratooning offers hope as a climate and resource smart technology. Crop duration in ratoon rice is reduced compared to the main plant crop. There is reduction in cost of cultivation. Input requirement is less in ratoon rice than to main planted rice crop. There is no seed cost since the ratoon crop is produced from the crop stubbles. This Experimental study suggests that application plant growth regulators significantly enhance the yield of ratoon rice. In that GA@ 5ppm gives the higher ratoon yield with higher B:C ratio among the all treatments.

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