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COMPARATIVE ANALYSIS OF SYNTHETIC AND HERBAL PLANT GROWTH REGULATORS ON RICE CULTIVATION: IMPACT ON GROWTH AND YIELD

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Abstract

The increasing global population has also increased the demand on rice production for future generation to secure their food. Therefore, to secure their dietary needs by rice production have a vital role. The productive potential of rice is mainly governed by many factors but deficiency of plant growth regulators (PGR) of plant develops a barrier to obtain higher yield. In this situation one of the important technologies is to increase the productivity of rice through application of PGR on rice crop is helpful. The treatments are T1: Control, T2: Moringa olifera leaf extract (10 % w/v), T3: Acacia nilotica leaf extract (10 % w/v), T4: Prosopis juliflora leaf extract (10 % w/v), T5: ISOBIAN (1000 ml), T6: STRIKER (120 ml), and T7: GEBBEX (25-gram). All the growth regulators were foliar sprayed at tillering stage of crop growth. The results revealed significant and non-significant variations for both of the varieties when subjected to different plant growth regulators. The PGRs STRIKER (naphthyl acetic acid @ 120ml ha⁻¹), GEBBEX (gibberellic acid @ 25 g ha⁻¹), and M. olifera leaf extract @ 10 % w/v proved to be effective in improving the physiological, agronomic and yield contributing parameters of coarse rice (KSK-133) as compared to the fine (Kissan Basmati). However, maximum leaf area index at 50 days after transplantation (DAT) were recorded by the plots treated with GEBBEX. Similarly, the maximum count of tillers, CGR, NAR, 1000-GW, count of spikelet pan-1, paddy yield (t ha⁻¹ and minimum sterility percentage, was recorded by the plot treated with STRIKER (naphthyl acetic acid @ 120ml ha⁻¹) in KSK-133 as compared to Kissan Basmati. Furthermore, in term of natural PGRs, moringa leaf extract improved the sterility (%) and paddy yield as compared to control and other plant extracts.

Keywords: Efficacy, Herbal, Plant regulators, Rice, Synthetic

INTRODUCTION

Rice (*Oryza sativa* L.) is a chief food grain as well as cash crop. It is the 2nd major cereal crop after wheat and second major exportable item after cotton in Pakistan (1). It is most widely utilized by large number of the people in the country and throughout the world. Its food offers good source of energy (2). Low grade rice is an important constituent of poultry feedstuff as well as manufacturing of alcoholic drinks such as beer and wine. As a livestock and poultry feedstuff rice enables animal production (3). In Pakistan the annual rice production during year 2020 – 21 was recorded 7.410 million metric tons and the total cultivated area under rice was 3,034 million hectares. Rice contributes 3.1% of agriculture value added and 0.6 % in GDP (4).

Due to ever increasing population, the demand on rice production has also increased. The potential of production of rice is influenced by many factors like soil types, fertilizer used, irrigation, genotypes used for planting and different agronomic practices. The productivity of rice has to be increased through adoption of suitable and newer technologies (5). Lack of PGR at any step of the plant could make it difficult to achieve significant grain yields (6). Plant growth hormones play an important role in activating and



inactivating gene expression, growth, and behavioral processes in plants. As a result, the introduction of chemical growth regulators has opened up new possibilities for modifying plant growth, development, and metabolism (7). Exogenously given hormones can also be stored in the form of reversible conjugates, which release active hormone when and where plants need it during the growth phase (8). Variations in temperature not only influence the growth interval but also the growth sequence of rice crop. During the growing period, the mean temperature, temperature sum, range, distribution pattern, and diurnal changes, or combination of these, may affect the growth and productivity of rice. Higher temperature is a perilous factor in rice grain production. Mostly high temperature induces higher sterility percentage and unfilled spikelets in the rice crop (9). Similarly, the application of various PGR's has been described for stimulating heat tolerance of rice crop (10). Amino acid used as a plant growth stimulator protect the plant against various abiotic stresses. So, the current research was intended to elucidate the potential of different herbal as well as commercial plant growth regulators on the germination and yield characteristics of fine and course rice cultivars (11).

Application of plant growth regulators has become an important factor in crop production, for example auxin and gibberellin are mostly used for reducing fruit drop and enhancing their quality (12). Similarly, PGR are the most widely used chemicals in crop production to enhance the crop growth and increase grain production (13). The application of amino acid as a plant growth promotor enhances the efficacy of plant metabolic processes to stimulate yield, improve crop quality, protect the plant against various abiotic stresses, uptake of nutrients, translocation and increases the quality attributes (11). Earlier findings reveal that the foliar application of gibberellic acid in combination with Naphthalene acetic acid recorded a maximum fruit set percentage on olive tree as compared to check treatment (14). The foliar application of moringa leaf extract on wheat crop reduces the salinity stress, increase yield and leaf area to enhance the process of photosynthesis (15). *Acacia nilotica* commonly known as "kikar" is a multipurpose fast-growing leguminous tree having the capability of fixing biological nitrogen due to its strong tap root system (16). Keeping in view, a research project was initiated to study the impact of PGRs on growth and yield characteristics of rice and to find out the best available "PGR" which improves the growth and yield of rice.

MATERIALS AND METHODS

A field trial was carried out Agricultural Research Institute, Dera Ismail Khan (277.0° North, 98.9019° East), Pakistan. The soil of site was silt loam having 24 % sand, 62 % silt, 14 % clay, pH 7.5, P₂O₅ 58 mgkg⁻¹, N 0.051 mgkg⁻¹, K₂O (58mg kg⁻¹), organic matter 0.21 %, porosity 46-57 %, bulk density 1.24 g cm⁻³ and electrical conductivity 1100.34 μS cm⁻¹. Two rice cultivars (Kisan Basmati and KSK-133) were used as test varieties. Seedbed for nursery raising was prepared by proper ploughing and planking. Soil was ploughed twice with cultivator followed by planking and once with rotavator. The paddy seed was kept immersed in water for twenty-four hours and then under moist gunny bags for 36 hours to a pigeon breast like shape, Seed at the rate of 25 kilogram per hectare for fine rice and 30 kilogram per hectare for course rice was used. The sprouted seed was broadcasted in the field on wet bed. The emerged seedling was transplanted in the main field after 30 days. The experiment was arranged in RCB design and replicated thrice with split-plot arrangement. The main plot was consisted of varieties and sub-plots with PGR's. The size of experimental units was 2.25 m² the P×P and R×R distance was maintained 20 cm and 2 seedling/hill at the depth of 4 cm was transplanted. Three (kg) fresh leaves of each (*Moringa olifera*, *Acacia nilotica* and *Prosopis juliflora*) was taken and washed with tap water. After properly cleaning, the leaves were shade dried for 15 days. The dried leaves were grinded with the help of electric blender and powder was made. The extract was prepared by dissolving 10-gram powder of each in 1000 ml of water (w/v). The recommended quantity of N₂: P₂O₅: K₂O was incorporated into the soil in the form of Urea, DAP and SOP. Half dose of Urea, full dose of DAP and SOP was applied during the time of seedbed preparation, remaining half quantity of Urea was applied 40 – 45 days after transplantation. The foliar application of PGR's (plant growth regulators) was done through knapsack sprayer at tillering stage. The application of plant growth regulators at tillering stage helps in maximum fruit set and reduces sterility percentage (17).

Data on leaf area index at 25 and 50 days after transplantation of rice, crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$), net assimilation rate ($\text{g m}^{-2} \text{ day}^{-1}$), days to 50 % heading (%), panicle length (cm), number of tillers (m^{-2}), number of spikelets (panicle⁻¹), sterility (%), 1000-seeds weight (g) and paddy yield (t ha^{-1}).

STATISTICAL ANALYSIS

Statistical analysis was performed using analysis of variance techniques (Statistics 8.1). Treatments were compared using LSD-test at the probability level 0.05.

RESULTS AND DISCUSSION

LEAF AREA INDEX AT 25 DAYS AFTER TRANSPLANTATION

The data collected for LAI at 25 DAT revealed non-significant variation for both varieties at $\alpha_{0.05}$. However, the differences between the treatment's means were found statistically significant (Table I). The results showed that maximum LAI at 25 DAT was (5.94) recorded for the treatment T₆ (GIBBREX) and followed by (5.65) recorded by the treatment STRIKER (naphthyl acetic acid). However, both treatments T₆ and T₇ were found statistically at par. Whereas, the minimum (3.14) LAI at 25 DAT was recorded in T₄ by the foliar application of herbal leaf extract *P. juliflora*. The application of moringa leaf extract (T₂) showed positive effect in improving the LAI at 25 DAT. The interaction between varieties and plant growth regulators were found non-significant. Similar results were found by the application of naphthalene acetic acid improved the physiological parameters of crops (18, 19). Similarly, the foliar application of plants with *M. olifera* leaf extract improved the number of leaves as well as leaf area index (20). The minimum leaf area index at 25 DAT was recorded in V₂ by the application of *P. juliflora* leaf extract.

LEAF AREA INDEX AT 50 DAYS AFTER TRANSPLANTATION

Leaf area index at 50 DAT showed non – significant differences for different varieties and their interaction with plant growth regulators (Table I). However, application of commercial and herbal extract showed significant effect on LAI at 50 DAT. The results revealed that maximum leaf area index (11.18) at 50 DAT were recorded in the treatment GIBBREX (gibberellic acid) which was statistically at par with (10.76) recorded for the treatment STRIKER (naphthyl acetic acid). The smallest leaf area index at 50 DAT was recorded in T₄ having osmopriming applied with phyto-hormone (*P. juliflora*) leaf extract. LAI is a structural feature of vegetation that indicates the area of ground occupied by plants. The principal sites of energy and mass exchange, as well as other critical processes like canopy interception, evapotranspiration, and gross photosynthesis, are all directly proportional to LAI (21). The findings are also in line with those of (22) who found that the application of gibberellic acid increased the leaf area index of rice.

CROP GROWTH RATE ($\text{M}^{-2} \text{ DAY}^{-1}$)

The data collected for crop growth rate (CGR) showed significant effect on two rice varieties (Table I). The coarse variety i.e. KSK-133 showed higher growth rate of $8.37 \text{ m}^{-2} \text{ day}^{-1}$ as compared to $6.59 \text{ m}^{-2} \text{ day}^{-1}$ recorded for fine variety i.e. Kissan Basmati. The treatment's means were also significantly different at $P_{0.05}$. The data showed in that maximum CGR $10.74 \text{ m}^{-2} \text{ day}^{-1}$ and $10.69 \text{ m}^{-2} \text{ day}^{-1}$ was recorded in T₆ and T₇ respectively. Foliar application of gibberellic acid on cereals stimulated the qualitative and quantitative traits of cereals (23, 24). However, the minimum CGR $3.54 \text{ g m}^{-2} \text{ day}^{-1}$ was recorded in T₃ *A. nilotica* leaf extract. The interaction amongst varieties and PGRs showed significant results at 5% level of significance. Maximum CGR 12.47 and $12.28 \text{ m}^{-2} \text{ day}^{-1}$ was recorded in coarse variety (KSK-133) by the application of GIBBREX 25 g ha^{-1} and STRIKER @ 120 mL ha^{-1} . The priming done with naphthalene acetic acid on hybrid sorghum increased the production of fodder (19). The application of herbal plant growth regulators (MLE and *P. juliflora*) performed best in enhancing the crop growth rate for coarse variety as compared to the data recorded for fine variety. The foliar application of moringa leaf extract proved to be effective in enhancing the yield and dry matter accumulation of rice (25). The positivity of *P. juliflora* was observed may be due the lower dosage of extract because Yadav *et al.*, 2021 described that by increasing the concentration of *P. juliflora* can inhibit the germination, growth, and development of crop plants(26). The minimum CGR was

Table I. Physiological parameters of rice varieties as affected by PGRs treatments

Treatments	Leaf area index			Leaf area Index			Crop growth rate			Net Assimilation rate (g m ⁻² day ⁻¹)		
	25 Days			50 days			(g m ⁻² day ⁻¹)			day ⁻¹)		
	V1 (Coarse)	V2 (Fine)	Mean	V1 (Coarse)	V2 (Fine)	Mean	V1 (Coarse)	V2 (Fine)	Mean	V1 (Coarse)	V2 (Fine)	Mean
T1: Control	3.93 ^{NS}	3.39	3.66 bc	7.13 ^{NS}	7.22	7.17 cd	5.63 f	4.40 g	5.02 e	1.0	0.88	0.96 c
T2: MLE	4.62	3.80	4.21 b	9.13	7.25	8.19 b	7.34 d	3.67 h	5.50 d	1.11	0.69	0.90 c
T3: <i>Acacia nilotica</i> Leaf Extract	3.84	3.04	3.44 bc	6.40	6.45	6.43 de	5.27 f	1.82 i	3.54 f	1.05	0.40	0.72 d
T4: <i>Prosopis juliflora</i> Leaf Extract	3.60	2.68	3.14 c	6.17	5.91	6.04 e	9.06 c	6.50 e	7.78 c	1.92	1.60	1.76 a
T5: ISOBIAN (amino acid)	4.20	3.58	3.89 bc	8.49	6.84	7.66 bc	6.52 e	11.64 b	9.08 b	1.07	2.31	1.69 a
T6: GIBBREX (gibberellic acid)	5.71	6.17	5.94 a	10.88	11.49	11.18 a	12.47 a	9.02 c	10.74 a	1.56	1.06	1.31 b
T7: STRIKER (naphthyl acetic acid)	6.60	4.71	5.65 a	10.86	10.66	10.76 a	12.28 a	9.10 c	10.69 a	1.50	1.25	1.38 b
Mean	4.64^{NS}	3.91		8.44^{NS}	7.79		8.37 a	6.59 b		1.32^{NS}	1.17	
LSD Var	Non - Significant			Non - Significant			0.32			Non - Significant		
LSD Treat	0.85			0.96			0.32			0.13		
LSD Int	Non - Significant			Non - Significant			0.51			Non - Significant		

Table II. Yield parameters of rice varieties as affected by PGRs treatments

Treatments	Number of tillers (m ⁻²)			Number of spikelet (panicle ⁻¹)			1000 kernels weight (g)			Paddy yield (t ha ⁻¹)		
	V1	V2 (Fine)	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
	(Coarse)	(Fine)		(Coarse)	(Fine)		(Coarse)	(Fine)		(Coarse)	(Fine)	
T1: Control	423.50 d	358.80 efg	391.15 c	11.82 ^{NS}	10.97	11.39 c	28.96 ^{NS}	26.60	27.78 ^{NS}	6.48 ef	5.16 hi	5.82 e
T2: MLE	435.30 cd	350.67 fgh	392.99 c	11.66	9.77	10.72 de	30.66	28.63	29.65	7.23 d	5.29 hi	6.26 d
T3: <i>Acacia nilotica</i> Leaf Extract	379.77 e	339.07 gh	359.42 d	10.86	10.33	10.59 de	28.20	28.10	28.15	6.19 fg	5.06 i	5.62 ef
T4: <i>Prosopis juliflora</i> Leaf Extract	378.00 ef	351.07 fgh	363.70 d	11.13	9.33	10.23 e	28.26	26.46	27.36	5.70 gh	4.95 i	5.32 f
T5: ISOBIAN (amino acid)	455.31 bc	329.69 h	392.17 c	11.93	10.17	11.05 cd	30.46	26.63	28.55	7.84 c	6.03 fg	6.93 c
T6: GIBBREX (gibberellic acid)	469.85 b	483.30 b	476.57 b	12.26	11.73	12.00 b	31.40	29.16	30.28	8.76 b	6.01 fg	7.38 b
T7: STRIKER (naphthyl acetic acid)	541.74 a	515.49 a	545.29 a	13.82	12.20	13.01 a	32.73	31.52	32.15	10.50 a	6.95 de	8.22 a
Mean	440.50 a	389.73 b		11.93 a	10.64 b		30.10^{NS}	28.16		7.67 a	5.63 b	
LSD Var	16.78			0.37			Non - Significant			0.15		
LSD Treat	18.76			0.59			Non - Significant			0.40		
LSD Int	28.56			Non - Significant			Non - Significant			0.54		

found in T3V2 by the application of herbal plant growth hormone (*A. nilotica*). The reduction in crop growth rate by the application of herbal leaf extract *A. nilotica* may be due the presence of alkaloids and phytotoxic chemicals. *A. nilotica* have showed both positive and negative effects on the germination and emergence of cereal (16).

NET ASSIMILATION RATE (G M⁻² DAY⁻¹)

Data regarding net assimilation rate is displayed in Table I showed non – significant effect of two varieties at $\alpha_{0.05}$. The data pertaining to differences between the treatment's means were found statistically significant at $P_{0.05}$. Data showed highest NAR 1.76 g m⁻² day⁻¹ recorded in T₄ (*Prosopis juliflora* leaf extract). The lowest net assimilation rate 0.72 g m⁻² day⁻¹ was recorded in T₃ herbal leaf extract of *A. nilotica*. The interaction amongst two factors (varieties and plant growth regulators) was found statistically non - significant.

NUMBER OF TILLERS (M⁻²)

Number of tillers (m⁻²) recorded after the harvest of rice crop showed significant difference between two varieties ($P < 0.05$). Coarse variety i.e. KSK-133 produced higher numbers of tillers m⁻² (440.50) as compared to 389.73 recorded for fine variety i.e. Kissan Basmati. Differences among the treatment's means were also found significant statistically at $P_{0.05}$ (Table II). The data depicted that highest count of tillers (545.29) was produced by T₇ (osmopriming with commercial plant growth regulator i.e., STRIKER having Naphthyl acetic acid @ 120 mL ha⁻¹). The lowest count of tillers m⁻² was noted in T₃ and T₄ the osmopriming done with herbal plant growth regulators ranked 359.42 and 363.70 tillers m⁻² respectively. Application of amino acid may have stimulatory effect on the growth performance of plants. as compared to control (27). Similarly, allelochemical exuded from herbal extract (*A. synophylla* and *P. juliflora*) have suppressing effect on the germination and growth in cereal crops (28). Interaction between two factors were also found significant. Highest number of tillers (541.74 m⁻²) were recorded in coarse variety KSK-133 by the application of STRIKER @ 120 mL ha⁻¹. Moreover, the lowest count of tillers m⁻² in comparison with local treatment was observed in T₃ and T₄ in which herbal plant growth regulators were used. Similar results were reported by (29, 30) who described that foliar spray of GA₃ and NAA increased the number of tillers/ hills. Because NAA (Auxin) increased the meristematic center at the base of primary shoot, ultimately these tissues converted into new tillers by vegetative growth. MLE used as herbal PGR on wheat proved effective in enhancing the morpho-physiological and yield contributing parameters which may be due to the presence of cytokinin in MLE which functions together with auxin (15).

NUMBER OF SPIKELET (PANICLE⁻¹)

Data recorded for number of spikelet (panicle⁻¹) was found statistically significant at $\alpha_{0.05}$. It was found that coarse variety i.e. KSK-133 showed highest numbers of spikelet (11.93) as compared to 10.64 in fine variety i.e. Kissan Basmati. The treatments means were also found significant statistically at $P_{0.05}$. The data offered in Table2 represented that the highest count of spikelet panicle⁻¹ (13.01) was found in T₇ followed T₆ recorded 12.00 number of spikelet by the application of synthetic PGR (plant growth regulator) i.e. STRIKER having NAA @ 120 mL ha⁻¹ and GIBBREX having 25 g ha⁻¹ Gibberellic acid. The minimum count of spikelet (10.23) was noted in T₄ (*P. juliflora*) by the application of herbal plant growth hormone. The application of gibberellic acid and naphthalene acetic acid proved to be effective in improving the qualitative and quantitative characteristics of rice (31). Interaction between both factors found statistically non-significant. Alike, trend of negativity was described by (32) who found that the application of herbal extract (*P. juliflora*) inhibited the germination, growth, and productivity of wheat.

1000-SEEDS WEIGHT (g)



The data about 1000-seeds weight (g) are presented in Table II depicted that the impact of different varieties on 1000-seeds weight were found statistically non-significant at $\alpha_{0.05}$. Differences between the treatment's means were also found non-significant statistically at $P_{0.05}$. Osmopriming done with gibberellic acid and naphthalene acetic acid improve the yield contributing factor of crop plants (33). The minimum 1000-seeds weight (27.36 g) was recorded in T4 by the application of herbal leaf extract (*P. juliflora*). Also, the interaction between varieties and plant growth regulators were also found non-significant statistically. The foliar application of gibberellic acid on hybrid rice increases the 1000-seeds weight (23, 34).

PADDY YIELD (t Ha⁻¹)

Grain yield being the ultimate target of any crop, the data regarding paddy yield revealed that both varieties were significantly different at $P_{0.05}$. The highest paddy yield (7.67 t ha⁻¹) was recorded by V1 (KSK-133) as compared to (5.36 t ha⁻¹) was recorded for V2 i.e. Kissan Basmati. Similarly, the influence of PGR's on paddy yield was also found significant at $P_{0.05}$. The data revealed that highest paddy yield (8.22) t ha⁻¹ was produced by T7 (STRIKER) followed by T6 (GIBBEREX) and T5 (IOBIAN) having significant differences in their mean values are 7.38 and 6.93 t ha⁻¹ respectively. Our results were in line with Sree *et al.*, (2021) who found that application of NAA and GA₃ improved the grain yield and biological yield of field pea (33). Similarly, the application of gibberellic showed a significant increase in paddy yield (23). Similar trends were described by Zia *et al.*, (2021) who found that aerial spraying of *M. oliefera* leaf extract improved the yield of maize. However, minimum paddy yield 5.32 (t ha⁻¹) was noted in T4 by the application of herbal plant growth hormone *P. Juliflora* (35). The interaction between varieties and plant growth regulators were also found significant statistically. Significantly, the highest paddy yield t ha⁻¹ (10.50) was documented by the combination of V1T7 (KSK-133 + STRIKER @ 120 mL ha⁻¹). However, the lowest paddy yield paddy yield t ha⁻¹ was noted by the application of herbal PGR *P. juliflora* leaf extract. The osmopriming done with moringa leaf extract increased the yield of rice under stress conditions (25).

STERILITY (%)

Data related to sterility percentage are presented in Fig. 1. The data pertaining to rice varieties and plant growth regulators statistically significant effect on rice sterility. Significantly highest percentage of sterility (16.81 %) was registered in the combination of V2T4 (Kissan Basmati + *P. juliflora* leaf extract) followed by V2T3, V2T2 and V2T5 having significant differences in their mean values were (14.31, 11.58, 10.09%) respectively. Meanwhile, the course rice treated with the same combination of plant growth hormones as discussed in V2 responded effectively for reducing the sterility percentage of V2 i.e. KSK-133.

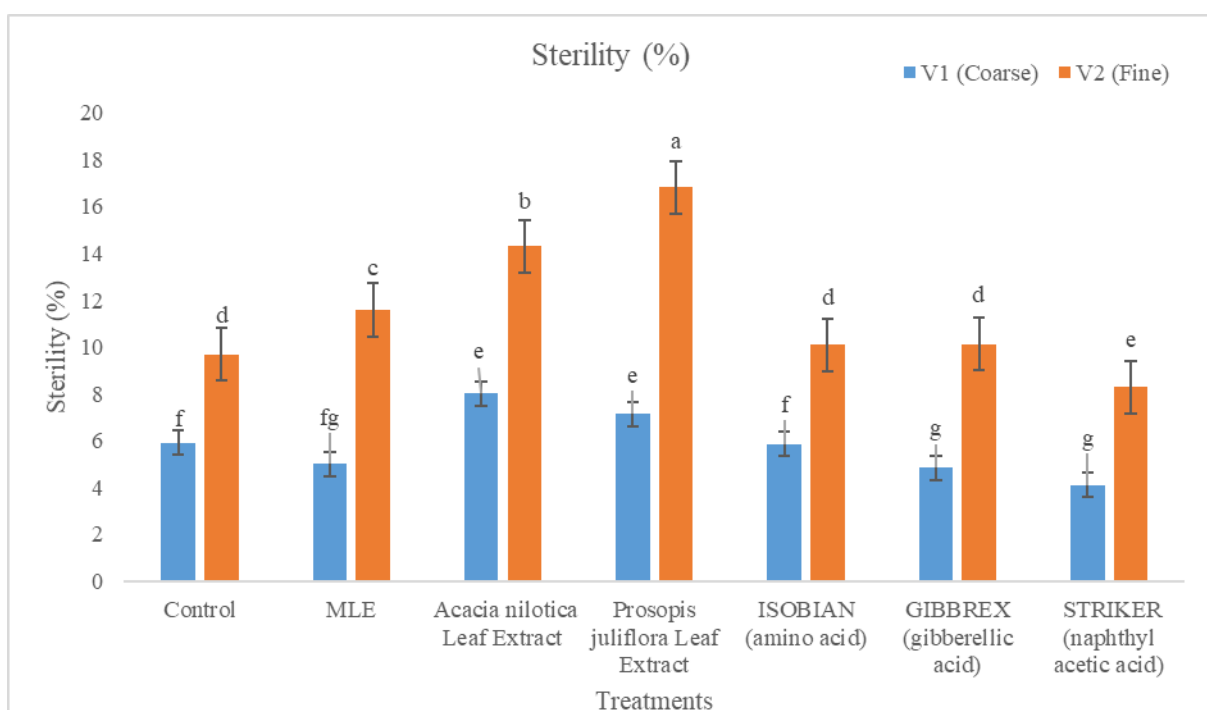


Fig. 1. Sterility (%) of rice varieties as affected by commercial PGRs and plant extracts

However, by the application of *A. nilotica* (T3) and *P. juliflora* (T4) also showed higher percentage of sterility in V2. Moreover, the application of GIBBREX indicated reduction in the sterility percentage for V1, while the treatment done with same PGR on V2 showed increase in sterility. Though, the percentage of sterility in V2 by the application of GIBBREX was lower as compared to the other treatments. The minimum sterility percentage was noticed in V1T7 by the application of STRIKER. The reduction in sterility percentage may be due to the presence of plant growth hormone (auxin) in NAA. Auxin might develop a floral hormone called florigin, which reduces the sterility in flowers during heat stress (36). Similar sort of trend was described by Jeber and Khaeim (2019) who found that the application of naphthalene acetic acid on fruit plant reduced the sterility percentage (37).

CONCLUSION

In conclusion, this research paper elucidates the significant role of tailored plant growth regulator combinations in augmenting the performance of fine and coarse rice cultivars. The synergistic application of STRIKER (120 ml/ha) showcased remarkable improvements in various agronomic, physiological, and yield-contributing parameters of V1 (coarse rice KSK-133). Coarse rice subjected to this regimen demonstrated heightened plant height, increased leaf area and enhanced tiller production. Furthermore, the utilization of this specific combination led to elevated chlorophyll content, enhanced Crop growth rate and Net assimilation rate. Notably, the culmination of these advancements translated into a substantial surge in sterility percentage, spikelets per panicle and grain yield. These findings underscore the potential of precision-controlled plant growth regulator combinations (STRIKER 120 ml along with KSK-133) as a powerful tool for steering the growth and productivity in agro climatic conditions of Dera Ismail Khan. As the agricultural sector faces the challenges of feeding an ever-expanding global population, such personalized interventions hold promise in contributing to sustainable and efficient crop cultivation practices. However, further research is warranted to comprehensively unravel the underlying mechanisms of this synergistic effect and to determine its adaptability to diverse agro-climatic conditions.

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