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Effects of various plant growth regulators and sowing methods on the growth, yield, and quality of rice (*Oryza sativa* L.)

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ABSTRACT

Rice (*Oryza sativa* L) is an important source of food, as the population of the world is increasing the additional supply of rice is requisite to feed the population. Moringa leaf extract, salicylic acid and zinc sulphate are excellent growth regulators used worldwide. A field experiment was conducted on rice at Bahauddin Zakariya University, Multan, Pakistan. Fine rice (super basmati) was sown by two methods (S_1= transplanting method and S_2= direct-seeded rice) supplied with three growth regulators G_1= moringa leaf extract (30 times diluted), G_2= salicylic acid (50 mg per liter) and G_3= zinc sulphate (50 g per liter) as foliar applications and G_0 devised as control treatment. Foliar application of growth regulators to respective treatments was done at two stages (before and after flowering). Data regarding growth (crop growth rate, photosynthetic rate and stomatal conductance), yield (number of grains per panicle, thousand grains weight, grain yield, biological yield and harvest index) and quality (normal kernel, sterile kernel, amylose contents, protein contents and brown rice rate) were studied. Compiled results of the study showed that moringa leaf extract along with the transplanting method performed better in most of the parameters than all other treatments. Transplanting with salicylic acid gave better results in the normal kernel, amylose contents and protein contents whereas zinc sulphate gave better results in brown rice rate.

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INTRODUCTION

Rice is the most important source of food all over the world. As the population increases there will be a need for more rice to meet food requirements (Choudhury and Chakraborty, 2006). Many factors limit the rice yield which may include poor irrigation, selection of inappropriate sowing methods and nutrition (Stoop *et al*., 2002). The inefficient sowing methods lead to a decline in rice yield so the best sowing method should be adopted according to conditions (Gill *et al*., 2006). To increase the productivity of rice growth enhancers are introduced which increase the growth of plants gradually and help the plants to sustain in tough conditions and increase resistance against diseases (Jetiyanon and Kloepper, 2002). Growth enhancers assist plants to grow properly and increase total dry matter (Cho *et al*., 2008).

Rice can be sown by different methods but in Asia mostly two methods are adopted transplanted and direct-seeded

rice (DSR). Direct-seeded rice is grown in a restricted amount of water and transplanted rice is generally grown in standing water (Hossain *et al*., 2002). Both sowing methods have pros and cons. Transplanted rice generally takes more water but is efficient in growth and yield. On the other hand, direct-seeded rice gives relatively less yield than the transplanted method, but it can save a large amount of water which can also be helpful to decrease the cost of production (Hashimoto *et al*., 1976).

Moringa leaf extract (MLE) is rich in zeatin, Fe, k, Ca and other essential nutrients. The exogenous application of moringa leaf extract is helpful to improve the growth of plants in the early stages and increases the yield (Basra *et al*., 2009). Zeatin which is found in moringa leaf extract helps boost cell elongation which ultimately increases the growth of plants (Nouman *et al*., 2012). MLE is widely used because of its capacity to enhance photosynthesis and other metabolic activities which makes it more valuable among growth enhancers (Abdalla, 2013).

Salicylic acid is also considered a growth regulator which is globally used by farmers to mitigate stress conditions and restore growth to successfully achieve the targeted yield (Shakirova *et al*., 2003). It is also regarded as a growth-regulating hormone that plays a vital role in the germination of the seed and in the growth and development of plants (Klessign and Malamy, 1994). Salicylic acid not only provides defense against tough environmental conditions, but it also provides some protection to plants against pathogens (Vicente and Plasencia, 2011).

Zinc is an important nutrient needed by the plant to manufacture its protein and obtain greenish color (Broadly *et al*., 2007). It is a major part of the human di*et al*so therefore it is desperately required by the human body (Keen and Greshwin, 1990). Zinc application in rice is helpful to acquire better shoot and root strength (Salton *et al*., 2001). The foliar application of Zinc assists crops in supporting their growth and improves grain contents (Yuan *et al*., 2013). This study is unified to observe the effect of different growth enhancers and sowing techniques on the growth and yield of rice crops.

MATERIAL AND METHODS

A field experiment was conducted in 2020 at the side of the research zone of Agronomy, Bahauddin Zakariya University, Multan, Pakistan, and was repeated next year during 2021. It was studied how different growth regulators (G_1=Moringa leaf extract, G_2=Salicylic $C_7H_6O_3$ and G_3=Zinc sulphate $ZnSO_4$) and sowing methods (S_1=Transplanting and S_2=Direct seeded) influence the yield and quality and physiology of rice. A fine variety of super basmati was chosen for this experiment. For transplanting methods, a nursery was prepared on a raised bed by a wet method for a period of 28 days.

The soil texture of cultivated area was tested following the way of (Dewis & Freitas, 1970). While the Physio-chemistry of the field soil was determined through the method of Jackson (1962). Results are presented in table.1. Metrological data for experimental years (2020 and 2021) were also recorded and shown in Fig.1.

The trial was conducted via a Randomized Complete Block Design with the split-plot arrangement. Foliar application of growth enhancers was done in both sowing methods two times (before flowering and after flowering) with the following concentrations, salicylic acid 50 mg L^{-1} of water, zinc sulphate 50 g per liter of water and 30 times diluted solution of moringa leaf extract in water. Recommendations about seed rate (transplanting 30 kg/ha and direct-seeded rice 70 kg/ha), fertilization (Nitrogen=100, Potassium=75 and Phosphorus 75 kilogram per hectare), and irrigation were followed. Nursery for transplanting and direct-seeded rice was sown on the same date and time.

Data Collection

The crop growth rate (g m^{-2} day) was calculated through the method of Hunt (1978);

$$CGR = W_2 - W_1 / t_2 - t_1$$

Where

W_1 = Plant dry weight at time t_1 (t_1 = time of the first harvest i.e., 50 days after sowing),

W_2 = Plant dry weight at time t_2 (t_2 = time of second harvest i.e.,100 days after sowing)

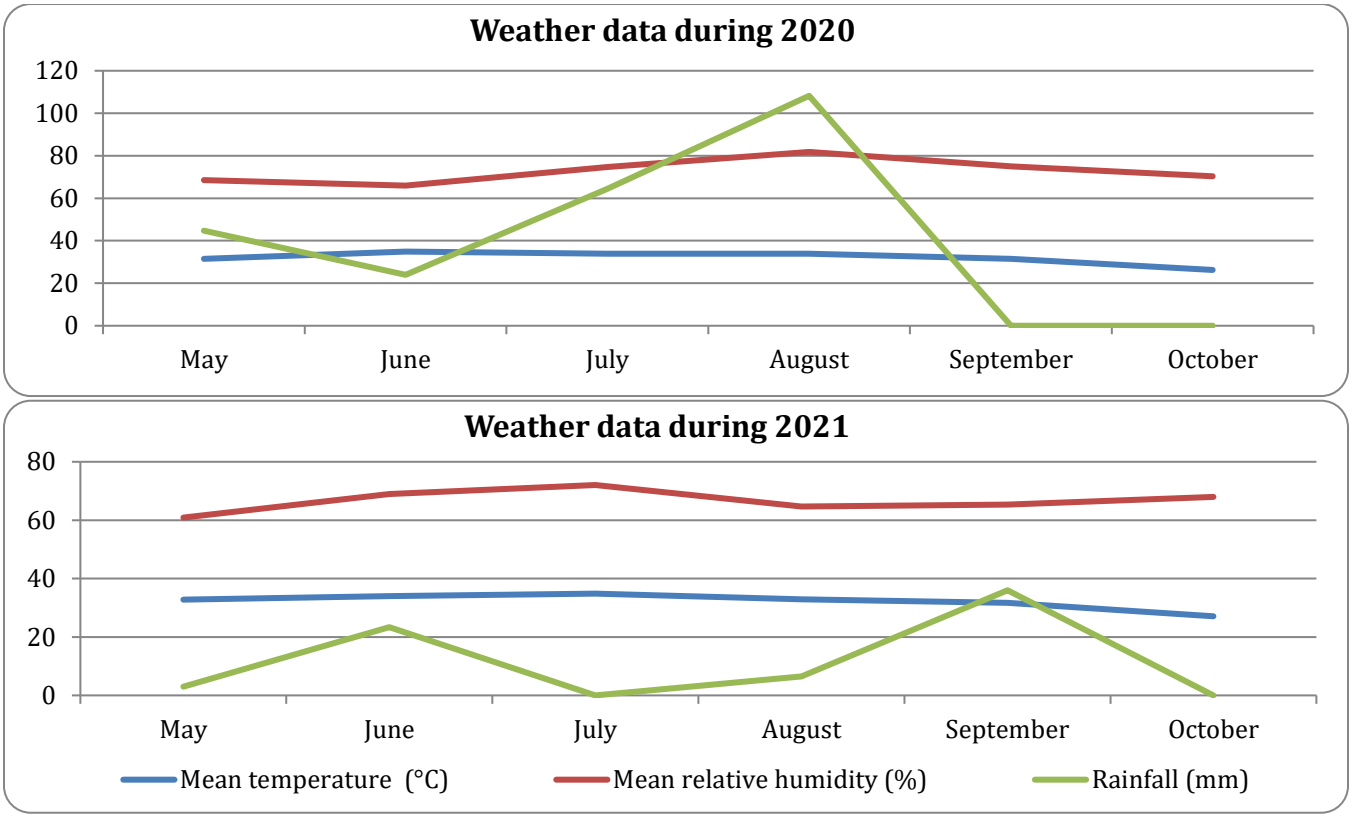
Photosynthetic rate (u mol CO_2 m^{-2} sec^{-1}) and Stomatal conductance (mMol H_2O m^{-2} sec^{-1}) both gas exchange attributes were recorded through a photosynthesis system (Infra-Red Gas Analyser – Model LI-6400 of LICOR inc., Lincoln, Nebraska, USA) apparatus alongside halogen lamp (6400-02B LED). Protein contents (%) in kernels were estimated by the method described in Bradford, 1976. Amylose contents (%) in kernels were estimated by the method described in Juliano (1971).

Data were statistically evaluated using Fisher's analysis of variance technique on P <0.05 to relate the variances among treatment results (Steel *et al*., 1997).

Table 1. Soil analysis of experimental soil.

Chemistry of soil	Values
pH (potential of hydrogen)	7.62
OM (organic matter)	0.64 %
Zn (zinc)	0.27 mg/kg
N (nitrogen)	0.041 %
K (potassium)	83.5 mg/kg
P (phosphorus)	2.98 mg/kg
Texture of soil	
Sand	20.5 %
Silt	48 %
Clay	31.5 %
Textural	Silt clay

Weather Data.



RESULTS AND DISCUSSION

During both years, yield attributes of rice were significantly affected by the application of plant growth regulators and different sowing methods (Table 2). Treatment S_1G_1 (Transplanting + moringa leaf extract) gave the maximum number of grains per panicle (67.33 and 67.77) while the minimum number of grains (52.13 and 52.51) was noted in treatment S_2G_0 during both years 2020 and 2021, respectively. 1000-grains weight (30.75g and 31.26g) was obtained more in treatment S_1G_1 (Transplanting + moringa leaf extract) and minimum 1000-grains weight (18.89g and 19.34g) was obtained in treatment S_2G_0 (direct-seeded rice + control) during the years 2020 and 2021, respectively. Maximum biological yield (13.41 and 13.59 t/ha) was obtained in the transplanting method along with the application of moringa leaf extract (S_1G_1) while direct-seeded rice with control treatment gave the minimum biological yield

(12.23 and 12.38 t/ha). Results of grains yield showed that treatment S_1G_1 (Transplanting + moringa leaf extract) perform better and gave maximum grains yield (6.3 and 6.41 t/ha) while minimum values (5.12 and 5.21 t/ha) exhibited by treatment S_2G_0 (direct-seeded rice + control) during both years, respectively. As concern harvest index, the highest values (48 and 48.18 %) were obtained in the transplanting method along with the application of moringa leaf extract (S_1G_1) while direct-seeded rice with control gave minimum (41.86, 42.08 %) values of harvest index during the years 2020 and 2021, respectively.

Results of both years of the normal kernel (%), sterile kernel (%) and brown rice rate (%) are shown (Table 2). Results regarding normal kernel, sterile kernel and brown rice rate were also significantly affected by plant growth regulators and sowing methods during both years. Normal kernel noted maximum (81.1 and 81.9 %) in treatment S_1G_2 (Transplanting + salicylic acid) while the minimum percentage of the normal kernel was noted in treatment S_2G_0 with values (77.97 and 78.73 %). For sterile kennel, treatment S_1G_1 (Transplanting + moringa leaf extract) perform better and gave a minimum percentage (6.45 and 6.4 %) of sterile kernel whereas a maximum percentage (9.41 and 9.33 %) of the sterile kernel was noted in treatment S_2G_0 (direct-seeded rice + control). While discussing the brown rice rate, treatment S_1G_3 (Transplanting + Zinc sulphate) achieve better results and gave a maximum percentage (85.87 and 85.9 %) of brown rice rate whereas the minimum percentage (83.71 and 83.77 %) of brown rice rate noted in treatment S_2G_0 (direct-seeded rice+control).

Table 2. Effect of sowing methods and plant growth regulators on yield attributes of rice during 2021 and 2021.

Treatments		Number of grains per Panicle		1000-Grain weight		Biological yield (t ha-1)		Grains yield (t ha-1)		Harvest index (%)		Normal kernel (%)		Sterile kernel (%)		Brown rice rate (%)	
S.M	PGR	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Transplanting	Ck	60.88 b	61.32 b	26.53 b	27.04 ab	12.44 ef	12.59 ef	5.33 f	5.42 f	42.84 ef	43.05 ef	79.02 ef	79.8 ef	7.74 b	7.69 b	84.2 d	84.23 d
	MLE	67.33 a	67.77 ab	30.75 a	31.26 a	13.41 a	13.59 a	6.3 a	6.41 a	48 a	48.18 a	81.13 ab	81.91 b	6.45 ef	6.4 ef	84.68 bc	84.71 bc
	SA	64.25 ab	64.69 ab	28.53 ab	29.04 ab	13.06 ab	13.21 b	5.95 b	6.04 b	45.56 b	45.72 b	83.14 a	83.96 a	6.12 f	6.07 f	84.79 b	84.82 b
	ZS	63.62 b	64.06 b	28.24 ab	28.75 ab	12.95 bc	13.1 bc	5.84 b	5.93 bc	45.09 bc	45.26 bc	80.72 bc	81.5 bc	5.76 g	5.71 g	85.87 a	85.9 a
Direct-sowing	Ck	52.13 c	52.51 c	18.89 ab	19.34 ab	12.23 f	12.38 f	5.12 g	5.21 g	41.86 f	42.08 f	77.95 f	78.73 f	9.41 a	9.33 a	83.71 e	83.77 e
	MLE	62.98 b	63.41 bc	27.92 ab	28.43 ab	12.83 cd	12.98 cd	5.72 cd	5.81 cd	44.58 b-d	44.75 b-d	80.3 b-d	81.08 b-d	6.76 de	6.71 de	84.55 b-d	84.58 b-d
	SA	62.11 b	62.55 b	27.6 ab	28.11 ab	12.71 cd	12.86 d	5.6 de	5.69 de	44.05 c-e	44.24 c-e	79.88 c-f	80.32 c-e	7.09 cd	7.04 cd	84.44 b-d	84.47 b-d
	ZS	61.49 b	61.93 b	27.28 c	27.79 bc	12.56 e	12.71 e	5.45 ef	5.54 ef	43.38 e	43.58 de	79.43 de	80.21 de	7.42 bc	7.37 bc	84.32 cd	84.35 cd

S.M=sowing methods, PGR=plant growth regulators application, Ck=control, MLE= moringa leaf extract, SA= salicylic acid and ZS= zinc sulphate, Treatment means showing the different letters are statistically different from each other, LSD at 5%.

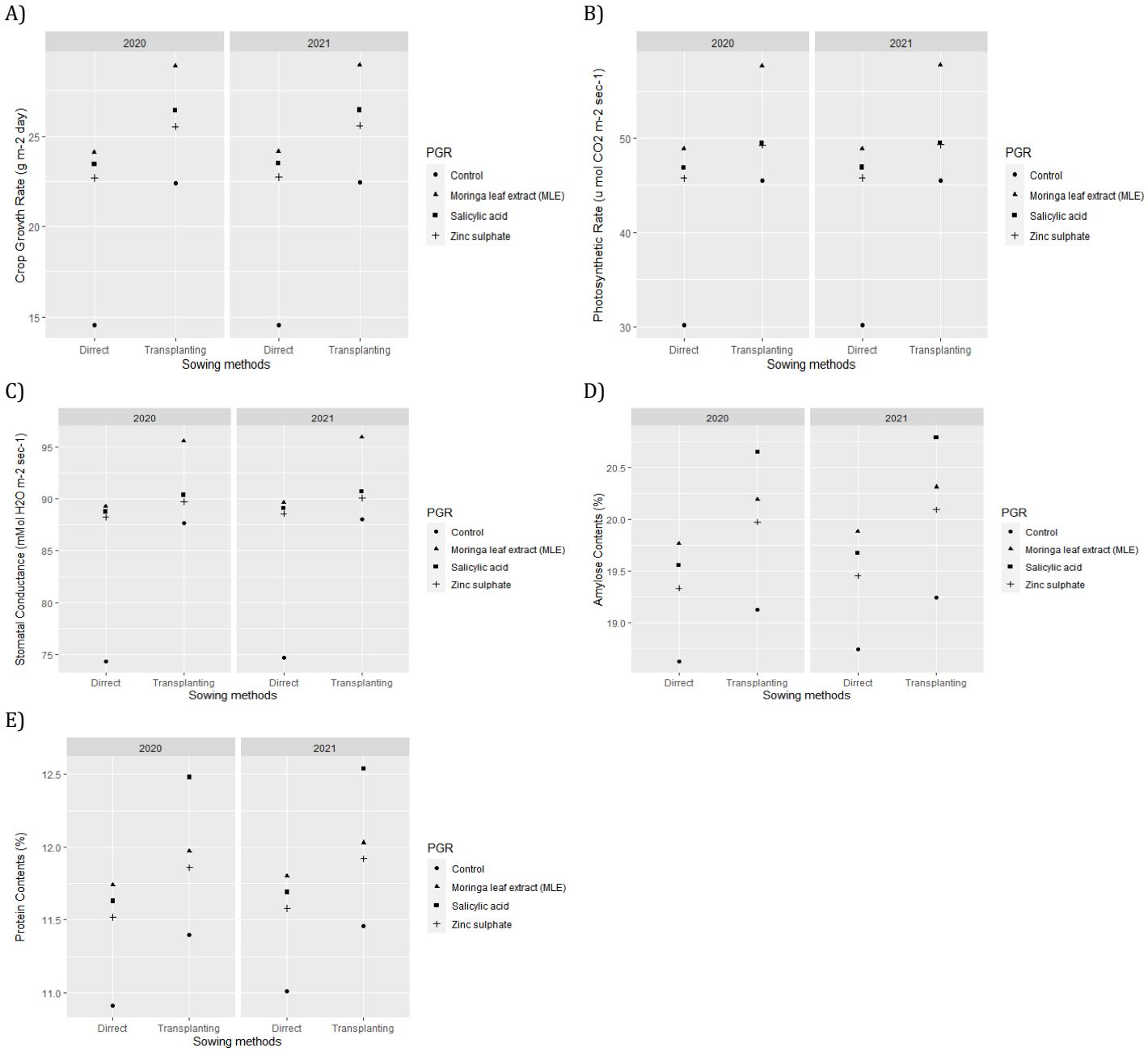


Fig. 2: Effect of different sowing methods and plant growth regulators on crop growth rate, (B) photosynthetic rate, (C) stomatal conductance, (D) amylase content (E) protein content during 2020 and 2021.

Crop growth rate (g m^{-2} day), photosynthetic rate (u mol CO_2 m^{-2} sec^{-1}), stomatal conductance (mMol H_2O m^{-2} sec^{-1}), amylose contents (%) and protein contents (%) were also significantly affected by plant growth regulators and sowing methods. The highest (28.88, 28.92) crop growth rate (g m^{-2} day) was obtained in treatment S_1G_1 (Transplanting + moringa leaf extract) whereas the minimum (14.55, 14.54) crop growth rate (g m^{-2} day) obtained in treatment S_2G_0 (direct-seeded rice + control). Results of both years of crop growth rate (g m^{-2} day) (Fig.2). Photosynthetic rate (u mol CO_2 m^{-2} sec^{-1}) obtained more (57.72, 57.750) in treatment S_1G_1 (Transplanting + moringa leaf extract), minimum photosynthetic rate (u mol CO_2 m^{-2} sec^{-1}) (30.14, 30.11) noted in treatment S_2G_0 (direct-seeded rice + control) during both years. Results of both years of photosynthetic rate (u mol CO_2 m^{-2} sec^{-1})

are shown in figure no.3.Stomatal conductance (mMol H_2O m^{-2} sec^{-1}) was noted highest (95.56, 95.92) in the transplanting method along with the application of moringa leaf extract (S_1G_1) while the direct-seeded method with control gave the minimum (74.33, 74.72) values of stomatal conductance (mMol H_2O m^{-2} sec^{-1}). Results of both years of stomatal conductance (mMol H_2O m^{-2} sec^{-1}) are shown in figure no.4.Results of all treatments about amylose contents (%) showed that treatment S_1G_2 (Transplanting + salicylic acid) perform better and gave maximum amylose contents (%) values (20.65, 20.23) while minimum values (18.62, 19.45) exhibited by treatment S_2G_0 (direct-seeded rice + control). Results of both years of amylose contents (%) are shown in figure no.5.As concern protein contents (%), the highest values (48, 48.18) were obtained in the transplanting method along with the application of salicylic acid (S_1G_1) while the direct-seeded method with control gave minimum (41.86, 42.08) values of protein contents (%). Results of both years of protein contents (%) are shown in the figure.

DISCUSSION

This study explored the effect of different growth regulators on the growth, yield and quality traits of rice crops sown by two sowing methods. All applied growth enhancers and sowing methods responded well to this study. Yield parameters like the number of grains per panicle, thousand-grain weight, grain yield, biological yield and harvest index were studied to figure out the best growth enhancer and sowing method. Moringa leaf extract + transplanting method produced a maximum no. of grains per panicle. Lower values were found in other treatments and lowermost values were observed in the control treatment of the direct-seeded method. A thousand grain's weight is an important characteristic of any crop. In this particular experiment, MLE supported the crop and provided essential nutrients which increased the thousand weights of the crop. The transplanting method can provide the required amount of water so that the potential of the crop to set maximum seeds and weight does not decrease. Grain/paddy yield, biological yield and harvest index observed maximum in MLE + Transplanting method. Salicylic acid and zinc sulphate along with the transplanting method were respectively behind the MLE application. Control treatment of the direct-seeded rice method showed minimum yield among all the treatments. Studies carried out by (Yasmeen *et al*. 2012) also support this study that MLE can be an excellent growth enhancer to directly influence the yield in normal and harsh environmental conditions. Other than MLE, Salicylic acid plays a vital role in increasing the yield (Deus *et al*., 2020).

Kernel quality was also determined, and the maximum percentage of the normal kernel was found in the salicylic acid growth enhancer. Because it provides better and more vigorous growth to the plant, so the plant produces a maximum number of good-quality kernels. Sterile kernels were less observed in the treatments where growth enhancers were applied, and a lesser percentage of sterile kernels were observed in treatment zinc sulphate + transplanting. In the control treatment, more percentage of sterile kernels was observed. As the growth enhancers help the plant to attain the required growth and development, plants produce a maximum number of normal grains so the sterility also decreased when the normal kernel percentage increases (Basra *et al*., 2011; Yasmeen *et al*., 2016). Brown rice rate perceived uppermost percentage by zinc sulphate application with transplanting method. Control treatment and DSR method showed a lower percentage of brown rice rate. It is evaluated that all growth enhancers had a significant impact on the quality trait-like brown rice rate.

The crop growth rate was determined which showed that moringa leaf extract (MLE) performed better among all applied growth enhancers with the transplanting method. Moringa leaf extract has Zeatin compound which helps plants to better grow in certain conditions. It is directly involved in cell elongation, so the growth rate gradually increases as the MLE is applied (Nouman *et al*., 2012). Different parameters like photosynthetic rate and stomatal conductance were also examined which revealed that MLE achieved the top place. On the other hand, Salicylic Acid and Zinc Sulphate were in second and third place respectively. Photosynthesis is the basic process of plants' which is associated with plants further growth and development (Lawlor, 1995). Stomatal conductance is the indicator of water use efficiency because it upholds the yield of the crop (Flexas *et al*., 2013). Foliar application of MLE can increase the photosynthetic and gas exchange traits in rice crops (Khan *et al*., 2021). Amylose contents percentage was witnessed maximum in salicylic acid application with transplanting method. Minimum amylose contents observed in control treatment of direct-seeded rice (DSR) method. Plant growth regulators assist assistance to the

amylose contents in grains so that grain quality should be maintained (Khan *et al*., 2021). Protein is one of the major portions of our diet. Protein contents were also examined most in salicylic acid application in the transplanting method. The lowest proportion of protein contents was observed in the control + DSR method. The conclusion of Mukamuhirwa *et al*. (2019) also supports this study that protein contents in grains are enhanced by the application of growth enhancers. In the end, it is recommended that moringa leaf extract (MLE) should be preferred on Salicylic ($C_7H_6O_3$) and Zinc sulphate ($ZnSO_4$) as growth regulators whereas more availability of irrigation water favors the transplanting method while low availability of irrigation water favors direct-seeded rice.

CONCLUSION

From compiled results, it is concluded that moringa leaf extract (MLE) along with transplanting rice gave significant results in most of the attributes and performed best against all other treatments. Moringa leaf extract can be preferably applied as a growth regulator to the rice crop. The transplanting method is the best method to grow rice but direct-seeded rice (DSR) can also be practiced in those areas where there is a shortage of irrigation water to achieve compensated results.

CONFLICT OF INTEREST

The authors declares that they have no conflict of interest.

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