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Performance of Main and Ratoon Crop for Boro Rice (*Oryza sativa* L.) in A Saline Soil of Southwest Coastal Region of Bangladesh

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ABSTRACT

Purpose: *Rice is an important source of carbohydrates to feed 9.7 billion people by 2050 and its productivity is adversely affected by salinity as a result of climate change. Ratooning after Boro rice (Oryza sativa L.) increases rice production at a low cost. This led to the carrying out of a field experiment in the saline soil of Batiaghata Upazila under the Khulna district of Bangladesh to investigate the performance of 1st and 2nd crops of five different rice varieties (BRRI dhan28, ACI hybrid dhan 6, KBP 1, BRRI dhan67 and Aftab LP 70).*

Research Method: *Three cutting height variations (20 cm, 30 cm, and 40 cm height from the soil surface level) of the second crop were introduced in this experiment which was conducted in RCB design with three replications.*

Findings: *Plant height, leaf area, biological yield, HI, total grains panicle^{-1}, and filled grains panicle^{-1} were significantly ($p \leq 0.05$) higher for the KBP 1 rice variety for the 1st crop. On the other hand, leaves hill^{-1}, number of tillers hill^{-1}, panicles hill^{-1}, grain yield, straw yield, and 1000 grains weight were significantly ($p \leq 0.05$) higher for Aftab LP 70 rice cultivar. In the 2nd crop, the plants died within 30 days after 1st harvesting due to the increased salinity.*

Research Limitations: *The result revealed that ratooning of rice can be possible in non-saline soil where available water is present otherwise it's not possible in high-saline soil as well as water deficit areas.* ***Originality/ Value:*** *The results of this experiment, suggested that KBP 1 or Aftab LP 70 perform better in terms of production of rice than the other varieties and rice ratooning is possible in the saline soil condition of the southwest coastal Bangladesh.*

Keywords: *Bangladesh, Boro Rice, Coastal area, Grain yield, Ratoon crop, Salinity.*

INTRODUCTION

Salinity, drought, heat, and flooding, are just a few examples of environmental stresses that plants encounter in a changing environment. These stresses have a negative effect on plant, yield, and productivity which puts the world's population's ability to feed itself at risk. Due to recent climate change, over one-fifth of Bangladesh's entire land area is now affected by fluctuating salinity that is rising at an alarming rate (Abedin *et al.*, 2023). One-third of the world's population relies on rice which is considered the most significant crop (Mayer *et al.*, 2008).

The degradation of soil quality caused by salinity results in decreased rice output and the conversion of rice fields into shrimp ponds, which lowers overall rice production. According to Kabir *et al.*, (2015), Bangladesh's population would reach 243 million by the year 2071 and each person requires 133.2 kg of rice per year (FAO, 2011).

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Though the population of Bangladesh is growing rapidly, either arable land must be added or per-hectare yield must be raised to feed up the excess population for economic stability. In the last two decades, Boro rice has been cultivated rapidly in waterlogged, low-lying, or medium lands with irrigation from November to May for rapid production of rice.

Rice ratooning is a natural occurrence and can be a helpful technique for increasing rice production per unit of land. In areas with the availability of water beyond the primary growing season, this method could be utilized in place of double cropping. Before planting Aman rice in Bangladesh, land remains fallow for 70 to 85 days following harvesting of Boro rice. Benefits of ratooning include lower input cost, improved water use efficiency, and reduction in cropping time due to a shorter growth period. Very few research works on ratoon were conducted, particularly in southwest coastal areas of Bangladesh. Mareza *et al.*, (2016) investigated the highest ratoon yield at the highest cutting height. Alridiwirsah *et al.*, (2021) and Harrell *et al.*, (2009) found cutting height at ground level resulted in the maximum ratoon output. Therefore, it is necessary to examine the performance of Boro rice varieties in the saline soil of Bangladesh, as well as ratooning. From the above discussion, this research was focused on the performance evaluation of the main and ratoon crops of various Boro rice varieties in saline soil.

MATERIALS AND METHODS

The field experiment was conducted in Batiaghata Upazila in the Khulna district of Bangladesh from December 28, 2021, to July 22, 2022. The study area's GPS coordinates were 22°42'N and 89°28'29"E. Five boro rice varieties (BRRI *dhan* 28, Chokkra hybrid, KBP 1, BRRI *dhan* 67, and Aftab LP 70) were tested in the study. Seeds of Aftab LP 70, ACI hybrid dhan 6, and KBP 1 variety were collected from the local market, and seeds of the other varieties were collected from Bangladesh Agricultural Development Corporation (BADC), Khulna. All the varieties have a life span of 135-150 days, suitable for ratooning. Randomized Completely Block Design (RCBD) was used in this experiment with 3 replications. Seedlings were transplanted in the main field at the age of 32 days. Data on morphological parameters including plant height, leaf area, leaf number, tiller number, panicles hill^{-1} and yield parameters (biological yield, grain yield, straw yield, harvest index, length of panicle, total grain number, filled grains, unfilled grains per panicle and 1000-grains weight (TGW) were collected. Five hills, with average growth and development, were selected randomly from each plot for collecting data. Textural class, pH, EC, OM%, and available N, P, K, and Na were also determined (Table 01). SPSS 16.0 was used to conduct a one-way analysis of variance for statistical analysis *[$p \leq 0.05$]*.

RESULTS AND DISCUSSION

Morphological Performance of the Main Crop

Morphological characteristics (height of plant, leaf area, leaves hill^{-1}, tillers hill^{-1}) of selected rice varieties have been shown in Fig. 01. Throughout the life cycle, the highest plant height (89.77 cm) was observed for KBP 1 rice variety which showed statistically higher height as compared with BRRI dhan 67 (84.11 cm) and Aftab LP 70 (76.44 cm) but was insignificant with BRRI dhan 28 (88.18 cm) and Chokka hybrid (85.44 cm). This study indicates that the KBP 1 rice variety is less susceptible to salt compared with the other cultivars. This might be due to the genetic makeup of the cultivars as well as the impact of Na ion that enters the rice shoots through the apoplastic pathway and reduces photosynthesis. This finding is similar to the findings of Islam *et al.*, (2022). The leaf area of KBP 1 was found to be the highest value (41.96 cm^2) whereas the lowest value (22.29 cm^2) was recorded for the Chokka hybrid rice cultivar. KBP 1 variety produced the highest green leaf area which was significantly different from the leaf areas of the other varieties studied. According to Islam and Hossain, (2020) and Wankhade *et al.*, (2013), this result may be caused by salt's detrimental influence on photosynthesis for many rice varieties, which reduces the growth of leaves.

Aftab LP 70 rice variety showed the highest leaf numbers hill^{-1}, tillers hill^{-1}, and panicles hill^{-1} which were 49.17, 19.97, and 17.11, respectively where the lowest value was observed at 21.89, 9.78, and 8.78, respectively for Chokka hybrid rice variety. Here, the Aftab LP 70 rice variety showed statistically significant variation in leaf, tiller, and panicle hill^{-1} than the other rice varieties tested. This result might be due to that salt-tolerant genotypes escape excessive salinity stress in the reproductive stage of life span. Results obtained from this study indicated that the varietal performance of salt tolerant capacity induced a reduction in the amount of panicle hill^{-1} which was also similar to the result of Kamal *et al.*, (2015). Furthermore, lower panicle was obtained for different cultivars due to lower accumulation of photosynthate of plant for the initiation of panicle production due to salinity stress which was similar to the findings of Sultana *et al.*, (2014).

Table 1: Properties of the Experimental Field's soil

Parameter		Unit	Value	Method
Texture		----	Silty clay	Marshall's Triangular co-ordinate
Organic Matter (OM)		(%)	2.19	Multiply OC by 1.73 (Van Bemmelen factor)
p^H		----	7.4	(Jackson, 1973)
Electrical Conductivity (EC)		(dS m^{-1})	8.1	EC meter (USDA, 2004)
Bulk density (D_b)		(g cc^{-1})	1.47	(Black,1965)
Available	N	ppm	28.53	(Chapman, 1965)
	P	ppm	39.78	(Murphy and Riley, 1962)
	K	ppm	276.37	(Benton, 2001),
	Na	ppm	30451.29	

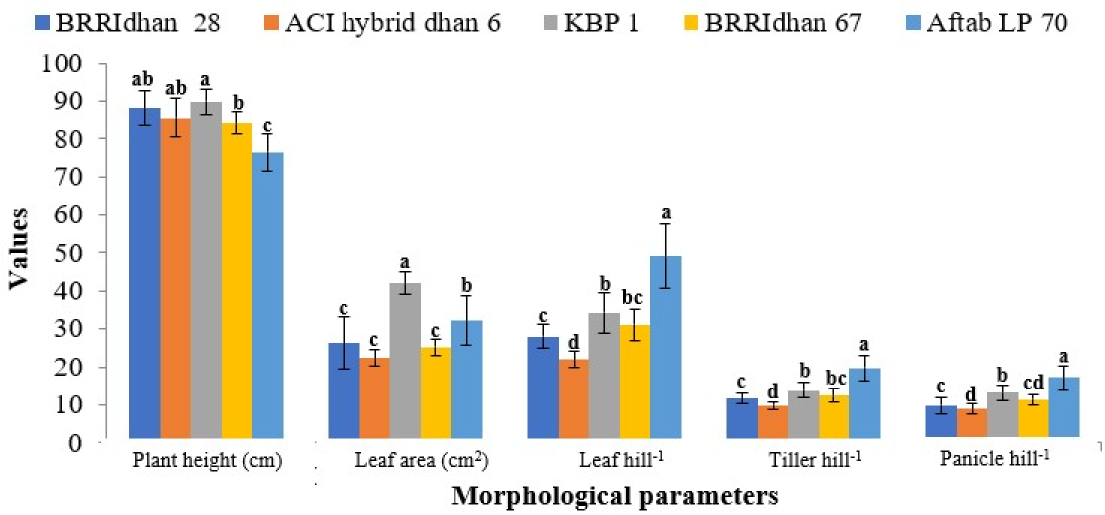

Figure 1: Morphological characteristics of the selected rice variety in saline soil condition (main crop).
Note: *The black vertical bars represent the standard deviation of the mean. The letters above the bars indicate the statistical differences among the varieties for different morphological characters, i.e., the same letters did not differ significantly from each other [p≤0.05].*

Yield Contributing Characteristics

Yield contributing characteristics (biological yield, straw yield, grain yield, HI) of selected rice varieties have been shown in Fig. 02. The highest biological yield (102.20 g $hill^{-1}$) was recorded for KBP 1 rice variety whereas the lowest biological yield 73.24 g $hill^{-1}$ was recorded for the Chokka hybrid variety. The highest grain yield was observed at 24.78 g $hill^{-1}$ for the Aftab LP 70 rice variety because of the highest number of effective tiller, filled grains, and TGW at the same time the lowest grain yield was measured at 14.72 g $hill^{-1}$ in the Chokka hybrid variety. Reduced spikelet number and harvest index contributed to the loss of grain yield under persistent salt stress situations. Hasamuzzaman *et al.*, (2009) showed that the fertility of grain is determined to be the most severely damaged among all these contributing factors evaluated, which significantly lowers the total yield of grain. This result was due to the salt stress tolerance phenomenon which was increased in plants that over expressed metabolic or biosynthetic genes for osmoprotectants or their precursors. It was also demonstrated that under salt-stress circumstances, grain production decreases were greater in a salt-sensitive variety than in a tolerant variety was also similar to the findings of Islam and Hossain, (2020) and Khanam et al., (2018). The biological yield and grain yield of KBP 1 were found statistically different compared with the Chokka hybrid, BRRI dhan28, and BRRI dhan67 variety but insignificant with the Aftab LP 70 rice variety. The straw yield was found to be the highest (60.62 g $hill^{-1}$) for the Aftab LP 70 variety which was significantly different from the Chokka hybrid (46.82 g $hill^{-1}$), BRRI dhan28 (47.74 g $hill^{-1}$) and BRRI dhan67 (47.99 g $hill^{-1}$) variety but was statistically insignificant with KBP 1 (51.76 g $hill^{-1}$) rice cultivar. The maximum harvest index (HI) was found for KBP 1 (29.16%) whereas the lowest HI value was recorded at 24.21% for the Chokka hybrid variety. On the other hand, HI was observed at 28.46%, 25.29%, and 27.89% for BRRI dhan28, BRRI dhan67, and Aftab LP 70 variety, respectively.

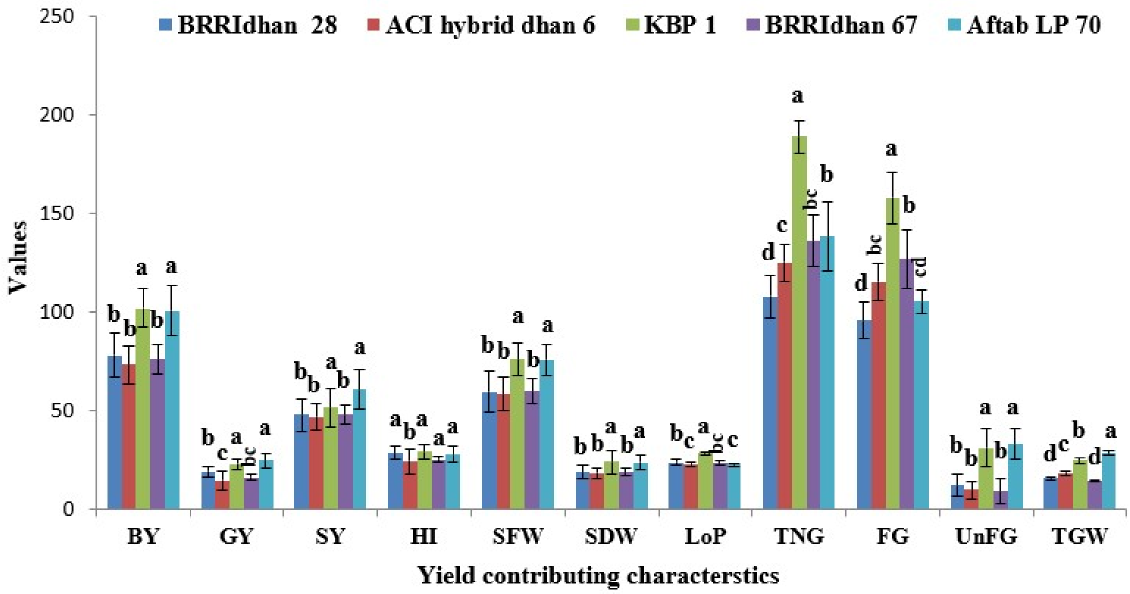

Figure 2: Yield characteristics of the selected rice variety in saline soil condition (main crop).

Note: *The black vertical bars represent the standard deviation of the mean. The letters above the bars indicate the statistical differences among the varieties for different morphological characters, i.e., the same letters did not differ significantly from each other [p≤0.05]. Here, BY = Biological Yield (g hill^{-1}); GY = Grain Yield (g hill^{-1}); SY = Straw Yield (g hill^{-1}); HI = Harvest Index (%); SFW = Shoot Fresh Weight (g hill-1); SDW = Shoot Dry Weight (g hill^{-1}); LoP = Length of Panicle; TNG = Total Number of grain panicle $^{-1}$; FG = Number of Filled grain panicle^{-1}; UnFG = Total Number of Unfilled grain panicle^{-1}; TGW = Thousand Grain Weight (g).*

KBP 1 produced the highest length of panicle (28.53 cm) which was significantly higher as compared with BRRI dhan 67 (23.42 cm), BRRI dhan 28 (23.81 cm), Chokka hybrid (22.38 cm) and Aftab LP 70 (22.38 cm) variety studied. The highest total grains panicle^{-1} (189.22) was recorded in KBP 1 rice variety followed by Aftab LP 70 (138.44), BRRI dhan67 (136.22), Chokka hybrid (125.11) and BRRI dhan28 (108.11). The highest filled grains panicle^{-1} (158.11) was found in KBP 1 rice variety which differed significantly from the other varieties; Aftab LP 70 (105.44), BRRI dhan67 (127.00), Chokka hybrid (115.44) and BRRI dhan28 (95.89). Similarly, the highest unfilled grains panicle^{-1} (33.00) was obtained in the Aftab LP 70 variety which was dissimilar with Chokka hybrid (9.67), BRRI dhan 28 (12.22), and BRRI dhan 67 (9.22) but statistically similar with KBP 1 (31.11) variety. Filled grain formation can be due to the accumulation of carbohydrates in the rice grain. The findings indicated that rice grain formation may be brought on by pollen viability, which may be the reason for the spikelet fertility.

Maximum 1000-grain weight was recorded for Aftab LP 70 (28.67 g) cultivar at 13% moisture level followed by KBP 1 (24.57 g), ACI hybrid dhan 6 (18.36 g), BRRI dhan28 (15.70 g) and BRRI dhan67 (14.43 g) that was statistically significant as compared with the other varieties. The fluctuation of 1000-grain weight depends on the genetic difference of the cultivar as well as the translocation of soluble sugars and starch synthesis in grain consequently impacting the fluctuation of grain weight. Our results are similar to the findings of Gerona *et al.*, (2019).

Morphological Characteristics of Ratoon Rice

Ratoon rice performance (morphological characteristics: plant height and tiller hill^{-1}) of the selected rice at different cutting height variations 15 days after 1st harvest was shown in Fig. 03. The highest plant height (49.66 cm) in the ratoon rice crop was observed in ACI hybrid dhan 6 at 40 cm cutting height (CH 40) whereas; the lowest height (20.26 cm) was obtained for Aftab LP 70 rice variety at 20 cm CH. Here, 40 CH produced the highest value than those of the other cutting heights in different varieties because of the ratoon shoots' ideal glucose supply, which encouraged and sustained the photosynthetic rate to produce assimilates that sped up the growth of the plant morphology.

Survival Percentage of 2nd Crop

Fig. 04. showed that the hill of different rice varieties at different CH decreased linearly from 10 days to 20 days after 1st crop harvesting. 40 CH performed better for all the rice varieties for survival though this percentage is not suitable for the cultivation of the ratoon crop. The highest percentage of alive hills (78.67%) was observed

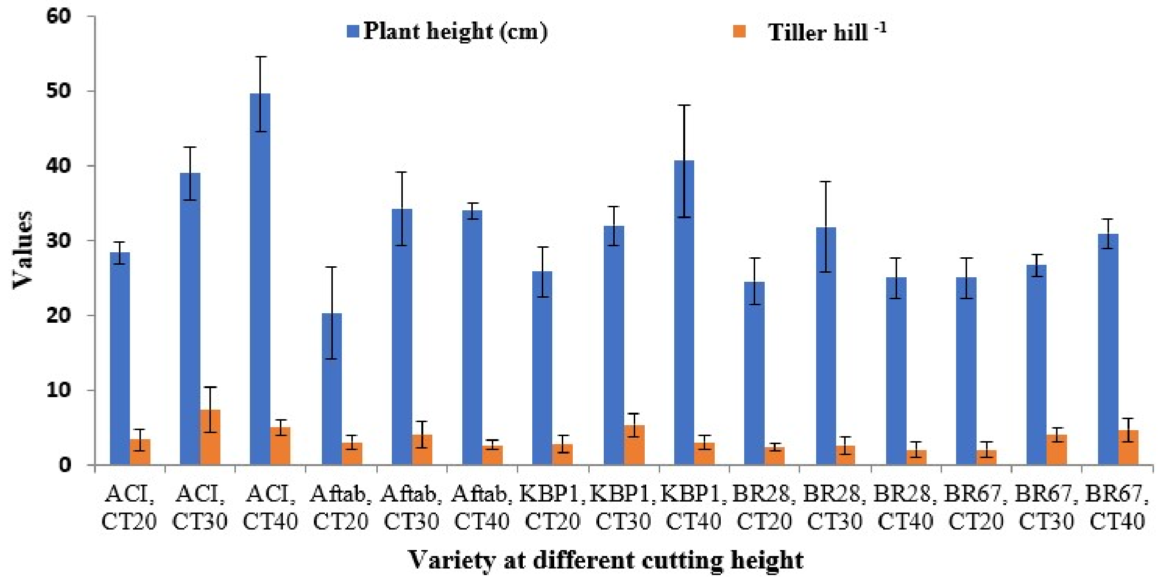

Figure 3: Morphological performance of selected rice variety at different cutting heights (ratoon crop).
Note: *The black vertical bars represent the standard deviation of the mean. The letters above the bars indicate the statistical differences among the varieties for different morphological characters, i.e., the same letters did not differ significantly from each other [p≤0.05]. Here, CH = Cutting Height.*

for KBP 1 rice cultivar in 40 CH at 10 days after 1st crop harvesting whereas the lowest value (31.67%) was observed for BRRI dhan28 in 20 CH at 10 days after 1st crop harvesting. On the contrary, the death rate of the hills was higher 20 days after 1st crop harvesting can be due to increased salinity. At 20 days, the highest percentage of survived hills (12.53%) was observed for the Aftab LP 70 rice cultivar at 40 cm CH. The cause of death after cutting 1st crop was due to the excess salinity in the root zone and shock of the plant after cutting the stubble which deteriorates hormone production and photosynthesis that damaged

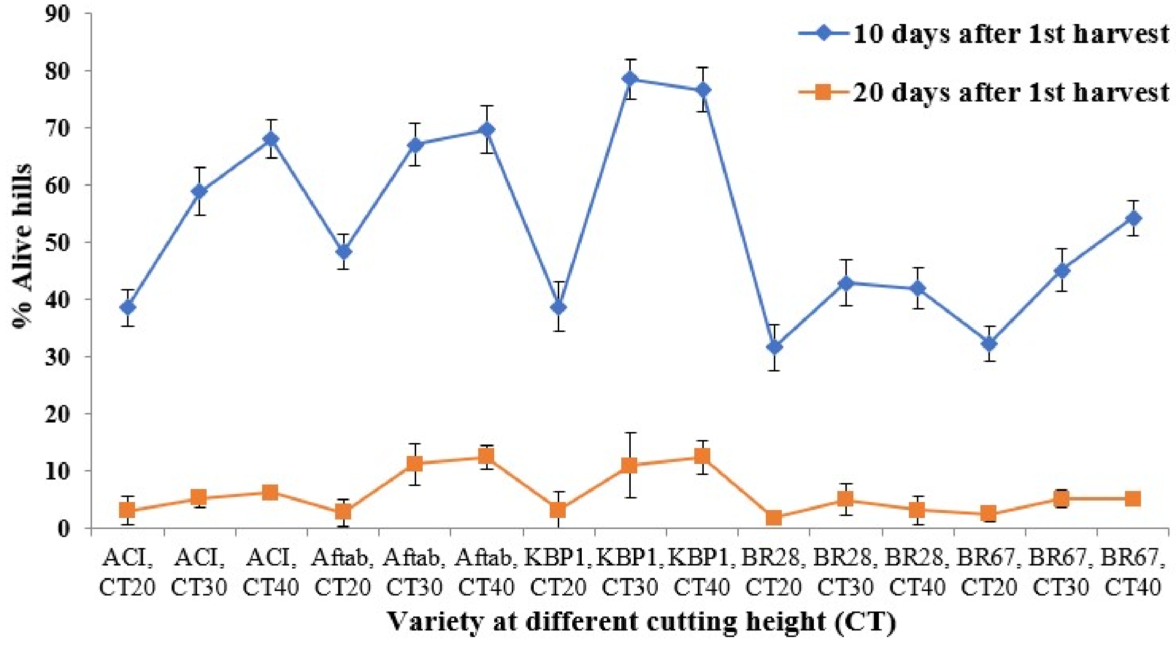

Figure 4: Survival percentage of selected rice variety at different cutting heights (ratoon crop).
Note: *The black vertical bars represent the standard deviation of the mean. The letters above the bars indicate the statistical differences among the varieties for different morphological characters, i.e., the same letters did not differ significantly from each other [p≤0.05].*
Here, CH = Cutting Height.

cell division thus leading to the death of the plant hill.

CONCLUSION

The findings of the research work indicated that KBP 1 and Aftab LP 70 rice varieties exhibited superior performance in terms of various morphological and yield-related characteristics. KBP 1 demonstrated higher plant height, biological yield, harvest index, total grains, and filled grains per panicle in the first crop, while Aftab LP 70 exhibited higher leaf number, tillers, panicles, grain yield, straw yield, and 1000-grain weight. These two varieties displayed a level of salt tolerance and resilience, suggesting their suitability for cultivation in saline soils. On the contrary, the experiment provides valuable insights into the potential of rice ratooning and the selection of suitable varieties for maximizing rice production in saline environments. The second crop in the experiment experienced high mortality within 30 days after the first harvesting due to increased salinity. This indicates that rice ratooning may not be feasible in this saline soil condition and can be possible in non-saline to slightly saline soil conditions with adequate water availability. Further research and interventions are necessary to address the challenges associated with salinity to optimize the potential of ratooning in saline environments.

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