Yield Response of Broadcast *Aus* Rice to Potassium Variation in the Coastal Soil of Southwestern Bangladesh

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DEDICATION

This thesis is dedicated to **my beloved parents** who sacrificed for me, inspired and blessed me in every way of my life.

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December, 2023 The Author

ABSTRACT

In the southwestern coastal region of Bangladesh, the cropping pattern is Fallow-Fallow-T. *Aman*, which leaves a large area of land fallow during Rabi and Kharif-1 season. However, a new cropping pattern has been emerging which incorporates broadcast (B) *Aus* rice before the monsoon season during early summer (Kharif-1). But the fertilizer requirement, particularly the potassium (K) rate, is still undefined. To address this issue, a field study was conducted with B. *Aus* rice (var. BRRI dhan48) in Pankhali, Dacope (a saline part of Agro-ecological zone, AEZ-13), Khulna. There were 6 different levels of potassium treatment such as 0, 20, 30, 40, 50 and 60 kg ha^{-1}. Potassium rates had statistically non-significant effects on plant height, grain yield and yield attributes (panicle length, number of grains $panicle^{-1}$, effective tiller m^{-2} and 1000 grain weight). At harvest, numerically the highest panicle length (23.3 cm) was produced by 40, 50 and 60 kg K ha^{-1} respectively. The numerical highest number of grain $panicle^{-1}$ (113.9) was produced by 50 kg K ha^{-1}. The numerical highest number of effective tiller m^{-2} (353.3), 1000-grain weight (22.8 g) and grain yield (4.49 t ha^{-1}) were produced by 60 kg K ha^{-1}. Grain yield and other measured parameters were not significantly increased with the application of K. The lowest nonsignificant values of almost all parameters were recorded from no K-added treatment. As there was no statistical yield variation was found due to variations of K, it seems that cultivation of B. Aus can be possible without the application of K but long-term of this practice (applying no K) will make the soil negative K balance. Thus, a maintenance dose of K 20 to 30 kg ha^{-1} could be suggested for recommendation for B. *Aus* rice in the coastal soil of southwest Bangladesh.

Key words: Dry seeding, salinity, potassium, coastal region, fertilizer, BRRI dhan48, yield.

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CHAPTER-I

INTRODUCTION

Agriculture in Bangladesh contributes around 14.23% of the GDP (Economic Survey, 2018). More than 30% of Bangladesh's net cultivable land is on the seashore. Soil salinity affects approximately 0.83 million hectares of arable land out of the 2.85 million ha of coastal and off-shore areas (Karim *et al.,* 1990). The salinity of the soil, groundwater salinity, and surface water salinity vary greatly in coastal saline locations (Mondal *et al.,* 2001).

Nonetheless, agriculture's contribution to GDP has recently declined due to salinity. The salt-affected region has grown by 14,600 ha annually (SRDI, 2001). Approximately 0.223 million ha (26.7%) of new land has been affected by varying degrees of salinity over the last four decades, severely limiting agro-biodiversity (SRD1, 2010).

Agricultural land is frequently inundated in seawater by tidal waves, coastal floods, and storms. Furthermore, it is currently threatened by sea level rise as a consequence of global warming (Abedin, 2010). The intrusion of salt water, waterlogging, sluggish water recession, soil evaporation during the dry season, and capillary rises from shallow saline underground aquifers all have an impact on soil salinity in this area (Gurung and Azad, 2013).

During the dry season, soil salinity limits normal agricultural production in Bangladesh's southwestern coastal area. Because of the high soil moisture content, most of the field stays fallow after harvesting *Aman* rice (i.e., in the winter season). Fresh irrigation water is scarce, and soil salinity continues to rise. The majority of coastal lands are single-cropped (Fallow: Fallow-Transplanted *Aman*) and farmed during the monsoon when soils become less or no salty. In winter and in Kharif-1 seasons farmers have little choice but to leave their land unused due to insufficient fresh water, excessive wetness of soil during Rabi crop sowing and soil drying during optimum sowing time of Kharif-1 crops. To overcome the current situation, some crops have been experimentally cultivated under zero tillage e.g., wheat, maize, sunflower, etc. and found good results (Kabir *et al.,* 2019; Bell *et al.,* 2019, Sarker *et al.,* 2023). Broadcasting *Aus* rice could be the right choice in Kharif-1 by sowing them directly just after the 1st summer rain and growing the rice on rainfed.

Rice is the staple crop in Asia, providing 71% of calories and 51% of protein for 160 million Bangladeshis (Haque *et al.*, 2016). With 90% of production and consumption (Hossain and Narciso, 2002), rice farming covers 80% of the cultivated area and yields 25.18 million tons from 10.29 million hectares (Alam *et al.*, 2009). However, demand for rice is increasing due to population growth, and sustainable and profitable methods are needed to increase yield. In the SW coastal region of Bangladesh horizontal expansion might be possible by replacing the fallow by rice crops.

Due to Fallow-Fallow-T. *Aman* cropping pattern the cropping intensity is low (145%) compared to that of other parts of the country (~200%, BBS, 2021). Transplanting of *Aus* is not possible due to seedling raising problems by high saline water in April and May (Mainuddin *et al.,* 2021). Recently, broadcasting (B) *Aus* rice has been emerging as a new crop during Kharif-1 but the fertilizer recommendation for B. *Aus* is not available although the recommendation for T. *Aus* is available in three cropping patterns (Rabi crops-T. *Aus*-T. *Aman*) for the SW coastal zone (AEZ 13, FRG, 2018). Hence, it is essential to determine the fertilizer requirement for B. *Aus* rice. In several experiments, it has been observed that the nitrogen requirement for B. *Aus* is nearly similar to that of T. *Aus* rice (Sumona *et al.*, 2022) and the phosphorus requirement ranges from 6 to 12 kg ha^{-1} (Ahmed, 2019).

The requirement of potassium (K) for this rice is still unknown. Hence, it is necessary to determine the K requirement as it is believed that K in the root zone minimizes the sodium (Na) uptake and keeps Na/K homeostasis in the root and shoot of plant grown in saline soil (Taiz and Zeiger, 2010). Determination of the K rate for *Aus* rice might increase the grain yield and make the cropping pattern intensive and profitable (Mainuddin *et al.,* 2021).

Thus, the current field experiment is designed to determine the optimum K requirement for B. *Aus* rice. The result of the study will contribute towards the increase in rice yield and productivity, food security and improved livelihood of the people of this region.

Objectives

- To examine the growth and yield response of broadcast *Aus* rice (BRRI dhan48) to different K rates in southwestern coastal region of Bangladesh.
- To find out the optimum rate of K for BRRI dhan48 in southwestern coastal region of Bangladesh.

CHAPTER-II

REVIEW OF LITERATURE

Reading the current literature to become acquainted with the material on the topic of interest is one of the most important preliminary chores before commencing a research project. According to Hart (1998), the literature review is "the use of concepts in the literature to support the particular approach to the issue, the selection of methodologies, and show that this research offers something unique". He also stated that "quality involves proper breadth and depth, rigor and consistency, clarity and brevity, and effective analysis and synthesis" for the literature review (Hart, 1998).

Before delving into how to perform a literature review, it is necessary to first comprehend the review's role in research (Webster and Watson, 2002). As a result, two questions must be addressed: What exactly is research? Why is a literature review required for each high-quality research project? (Levy and Ellis, 2006).

The objective of a review is discussed first, followed by a taxonomy of literature reviews and the stages of doing a quantitative or qualitative literature review (Randolph, 2009). It is not for everyone to write literature reviews. It is an activity best suited to persons who are adept at detecting patterns in huge amounts of data, who like writing and thinking (possibly more than they enjoy collecting and analyzing data), who appreciate thinking about broad issues, and who have a wide range of interests (Baumeister, 2013).

2.1 Rice production, its importance on the global perspective

Rice is the second most widely grown cereal crop and the staple food for more than half of 3.5 billion people, with an average annual growth rate of 0.39% over the last 30 years, but its area under cultivation has decreased due to limited returns, declining productivity, pressures from abiotic and biotic stresses, low returns in developing countries, rising production costs in developed countries, and growing public concern for environmental resources (Chauhan *et al.,* 2017). Global rice output is currently expected to be in the range of 512 million tons (milled), 1.2 million tons lower than the December prediction and 2.6 percent lower than the all-time record set in 2021 (FAO, 2023). Rice output reached new highs in the latter three decades of the twentieth century. Between the 1940s and the late 1960s, the Green Revolution increased agricultural productivity in developing nations, mostly via the transfer of a number of research and technology programs (Muthayya *et al.,* 2014).

Rice is essential for the nourishment of a large portion of the people in Asia, Africa, South America, and the Caribbean. Rice is vital to the food security of more than half of the world's population (FAO, 2006). Rice accounts for 20% of the world's dietary energy supply, whereas wheat accounts for 19% and maize accounts for 5% (Bin Rahman and Zhang, 2023). Rice is a prominent cereal grain that is widely used for human nourishment.

Table 1. Paddy production by economic group and region and major players (FAO, 2006)

Production By Economic Grouping and Region	2000-2005	2000-2005 Share in World	2000-2005 Accumulated Share
	000 tonnes	%	%
World	599,641	100.0	
Developed	25,449	4.2	
Asia	543,347	90.6	
Latin America & Car.	23,882	4.0	
Africa	18,591	3.1	
North America	9,621	1.6	
Europe	3,284	0.5	
Oceania	916	0.2	
Major Producing Countries	**000 tonnes**	**%**	**%**
China total	178,391	29.7	29.7
India	128,203	21.4	51.1
Indonesia	52,371	8.7	59.9
Bangladesh	38,199	6.4	66.2
Vietnam	34,266	5.7	71.9
Thailand	27,747	4.6	76.6
Myanmar	22,726	3.8	80.4
Philippines	13,719	2.3	82.7
Brazil	11,477	1.9	84.6
Japan	11,048	1.8	86.4
United states	9,621	1.6	88.0
Pakistan	7,142	1.2	89.2
Korea, Republic of	6,769	1.1	90.3
Egypt	5,980	1.0	91.3

2.2 Rice in Bangladesh

According to rice database of BRRI, 2023f, Bangladesh's year-wise rice production in FY 2019-20 was 3,86,95,330.00 ton with a 3.56% growth rate. Bangladesh exported 4,000.00 tons of rice in 2017 and imported 11,00,000.00 tons of rice in 2018 (BRRI, 2023c). Bangladesh has single cropped area of 2,133.06 ha, double-cropped area of 4,073.09 ha, triple cropped area of 1,859.10

ha, net cropped area of 8,082.64 ha and 197% cropping intensity in FY 2018-19 (BRRI, 2023d). The lower revision for rice output in China more than offset upward revisions for numerous other nations, most notably Bangladesh, despite some rainfall-related difficulties at the planting stage (FAO, 2023).

The estimated total cultivated area under *Aus* rice in FY 2019-20 was 1,134.00 ha, yield was 2.66 ton/ha and production was 3,012.00 ton in Bangladesh (BRRI, 2023d). Total *Aus* rice area in FY 2019-20 was 1,034.59 ha for modern variety, 99.40 ha for local variety and yield was 2.75 t ha^{-1} for modern variety, 1.40 t ha^{-1} for local variety (Table 2).

Table 2. Total rice (*Aus, Aman* and *Boro*) area (000'ha), production (000'ton) and yield (t ha^{-1}) of Bangladesh (BRRI, 2023d), (BRRI, 2023e), (BRRI, 2023f)

Year	Area (000'ha)			Production (000'ton)			Yield (t ha^{-1})		
	Aus	*Aman*	*Boro*	*Aus*	*Aman*	*Boro*	*Aus*	*Aman*	*Boro*
2016-17	**941.70**	**5,583.30**	**4,547.30**	**2,133.60**	**13,656.00**	**18,411.80**	**2.27**	**2.44**	4.05
2017-18	1,075.10	5,679.50	4,859.40	2,709.70	13,993.80	19,575.80	2.52	**4.03**	**4.03**
2018-19	**1,145.13**	5,621.90	**4,909.85**	2,920.20	14,054.90	**20,388.50**	2.55	2.50	4.15
2019-20	1,134.00	**5,883.80**	4,754.40	**3,012.00**	**15,502.00**	20,181.40	**2.66**	2.63	**4.24**

2.3 Cultivation process

Different varieties of rice are cultivated in different environments all over the country including coastal areas. During dry season, soil and river water become saltier while in the monsoon season, the salinity decreases. Land use varies temporally and spatially with season. Coastal areas remain fallow during winter due to salinity. Shelley *et al.,* (2016) reported that wet-season *Aman* is the main crop and traditional rice varieties are mostly used, which can withstand salinity but have poor yield. Salinity causes nutrient deficiencies, especially N and P, and limits Cu and Zn micronutrients, leading to reduced yield (Shelley *et al.,* 2016).

Usually, puddling process is followed for rice cultivation. But due to salt water puddling is not possible in the southwestern coastal region of Bangladesh. The majority of coastal lands are single-cropped and alternative one crop remains here in the southwestern coastal region of Bangladesh.

To make one to more crops, when the first shower of summer rain occurs, salinity in the soil remains minimum than in other normal situations. Soil is saturated with water in the mid of April-May. Then tillage is applied in the field and seeds are directly sown in the field in rainfed condition. *Aus* crops are grown depending on rainwater here.

2.4 BRRI dhan48

BRRI dhan48 is a cultivar of rice developed for the *Aus* season. The variety was approved by the National Seed Board in 2008 (BRRI, 2023a).

With a plant height of 105 cm, the cultivar is a high-yielding and early variety. The life span of the transplanted breed is 110 days. BRRI dhan48 yields 5.5 t ha^{-1} if properly cared of. Seeds are sown in seedbeds during 5-17 Baisakhi (18-30 April). The grain is medium coarse and white. The protein content in rice is 8.5% (BRRI, 2023a).

Fertilizer management for transplanted rice is 20 kg/bigha Urea, 7 kg/bigha TSP, 10 kg/bigha MoP, 5 kg/bigha Gypsum and 0.7 kg/bigha zinc sulfate. The land should be kept free of weeds for at least 30-40 days after transplanting. Approved pest control measures should be followed. Paddy can be harvested between 30 Shravan to 20 Bhadra (August 15 to September 4). BRRI dhan48 can prevent leaf blight disease to some extent (BRRI, 2023a)).

2.5 Historical background of salinity in coastal regions of Bangladesh

The area impacted by salinity in Bangladesh's coastal regions has grown considerably in recent decades (Baten *et al.*, 2015). According to SRDI research, salinity harmed 10,56,000 ha of land in 2009, up from roughly 8,33,000 ha in 1973. As compared to the base year of 1973, the rate of increase in the salinity-affected area was larger in the southwestern region (21% rise) than in the south-eastern region (3% increase) (SRDI, 2010).

According to Islam *et al.* (2021), the central coastal zone has seen the greatest increase in salinity and a significant rise in salinity was seen in the affected areas, as measured by a relative electrical conductivity of ECe $\geq$ 8.0 or higher.

Bangladesh's coastal polders have lower crop intensity and agricultural production due to waterlogging, the late harvest of the rainy season rice crop, and a shortage of fresh water during the dry season (Bhattacharya *et al.,* 2019).

Khanam *et al.* (2018), reported that salinity significantly decreased the total grain number, filled grain number per plant of *Aus* cultivars as well as BR55 showed relatively higher tolerance to salinity than BR43 on the basis of growth and yield performance.

2.6 Soil Potassium

Overall worldwide K reserves from salt deposits are estimated to be in the range of 9- 20×10^9 tons K_2O, which is sufficient to meet total current K consumption for at least another 350 years (Johnston, 2003).

Dobermann and Fairhurst (2000) assumed that potassium saturation (% of total CEC) is a better measure of soil potassium supply. They proposed rice ranges as follows:

1. K saturation <1.5% denotes low potassium status in rice fields, reaction to potassium fertilizer is certain.

2. K saturation of 1.5%-2.5% indicates medium potassium level in rice soil, reaction to potassium fertilizer is expected, and

3. K saturation >3.5% shows high potassium content in a rice field, reaction to potassium fertilizer is unlikely (Dobermann and Fairhurst, 2000).

2.7 Potassium in Plant Body

As a macronutrient, K is essential for plant development and long-term crop production. Potassium (K), one of the three main nutrients, is taken up by plants in greater quantities than any other element save nitrogen (N) (Bukhsh *et al.*, 2009).

Potassium (K) is essential for the activation of more than 60 enzymes (Tisdale *et al.*, 1990). It is not only a part of plant structure, but it also serves as a regulator in various metabolic processes (Hasanuzzaman *et al.*, 2018).

It keeps the cell's turgor pressure stable, which is essential for cell growth. It aids in plant cell osmoregulation and the opening and shutting of stomata (Bukhsh *et al.*, 2010). Its use has a primitive influence on growth and development, synthesis, glucose metabolism, and enzyme activation (Brar and Singh, 1995).

Potassium makes plants more resistant to biotic and abiotic stresses such as salt, drought, water logging, high temperatures, and ion toxicity because it includes osmotic control and competition with sodium; salt tolerance is directly related to potassium levels (Reddy *et al.*, 2002).

2.8 Potassium, -its importance and effects on rice production

A number of works have been done in various parts of the world on the nutrition of rice. Among the nutrition elements derived from soil, rice's K need is occasionally satisfied via plant residues, straw inclusion, and K in irrigation water. Since K in crop wastes is mostly water soluble, it may easily migrate into the soil solution and the soil exchange complex. In lowland rice soils, K fertility and nutrition are crucial for optimal fertilizer use (DeDatta and Mikkelsen, 1985).

In Brazilian circumstances, lowland rice reacted positively to K fertilization, with mean grain yields increasing 14.3% in the first two years and 10.4% in the last two years; Potassium was quickly taken from the soil, and an annual broadcast or banded application of K can result in a large boost in grain output (Fageria *et al.,* 1990).

According to Kundu *et al.* (2021), combining KH and KS resulted in significantly increased grain K absorption, which was 21% higher than the control. 69–76% of the total K intake by rice was partitioned into the straw, 13–18% into the grain, and 11–16% into roots. The straw K absorption was 54% and 48% greater in the only foliar KH treatment than in the control and soil application of K_2SO_4, respectively (Kundu *et al.,*2021).

Potassium fertilization boosted rice grain yield substantially. Rice's internal N usage efficiency declined as K rates increased. K fertilizer reduced the soil's negative K balance (Islam and Muttaleb, 2016). When nitrogen and phosphorus were coupled with K fertilization, yield tended to be highly responsive to plant K levels; it was the optimum treatment combination for increased yield production. K fertilization considerably impacted rice plant development and output, and their impacts on insect density and grain were reported across treatments (Sarwar, 2012).

In rice, a lack of potassium can diminish grain yields and promote lodging. The visual indications of K shortage in rice occur first in the older leaves. The symptoms include yellowing of leaf tips, less disease resistance, and lower yields. Proper K nutrition is connected with increased stalk strength and less lodging (Dunn and Stevens, 2005).

The role of potassium in resistance is well known; the stalk strength of rice plants was seen to increase with improved K nutrition, and enhanced stalk strength and decreased lodging are connected with optimal K nutrition (DeDatta and Mikkelson, 1985). In rice plants, K deficiency increased food intake and assimilation, honeydew excretion, growth index, adult lifespan, and insect population expansion. Although large doses of K applied to rice plants reduced the adult life and population growth of the insect (Salim, 2002),

According to Singh *et al.* (2003), K has been shown to provide disease resistance, and a high concentration of K ions in cell sap inhibits insect assault. Dong *et al.* (2010) discovered a significant positive association between K fertilization and grain abundance, suggesting that K fertilization is critical for maintaining high yield. Increases in the rice plant's tillering ability and spikelet output were ascribed to the yield advantage. Potassium was essential in plant physiology because it regulated activities such as transpiration, starch synthesis, sucrose translocation, respiration, and lipid synthesis (Tisdale *et al.,* 1985).

2.9 Effects of K on grain yield and yield components

Four yield components improved with K fertilization. An adequate supply of K enhanced root rowth, N metabolism-related enzyme activities, and the amount of non-structural carbohydrates in the stem, which may have increased N nutrition absorption, rice's intrinsic buffering capacity for grain filling, and yield contribution (Xu *et al*., 2023).

Razzaque *et al.* (1990) conducted a field experiment in two soil series (Lokdeo and Ghatail) in Mymensingh, and the findings showed that potassium had a considerably favorable effect on rice in both soil series. At 83 kg K ha^{-1}, the maximum straw yield was reported.

Devendra *et al.* (1999) discovered that applying potassium increased both straw and grain output. Nevertheless, the benefit was confined to the use of 30 mg K_20 in both grain and straw. The combined use of 60 mg N and 30 mg K_20 showed most beneficial in improving rice grain and straw production.

The findings of the two-year experiment show that the interaction of N and K (N_{90} K_{60}, N_{90} K_{120}, N_{18} K_{60}, and N_{180} K_{120}) can boost rice production even more than a single supply of N (N_{90} K_0 and N_{180} K_0) or K (Hou *et al.*, 2019; Zhang *et al.*, 2019).

Thakur *et al.* (1993) investigated the effect of potash treatment on wetland rice and discovered that increasing the potassium level up to 66 kg ha^{-1} increased the number of total tillers m^{-2}.

Meena *et al.* (2003) studied the productivity and economics of rice (*Oryza sativa L.*) as affected by K application in a field experiment at the Indian Agricultural Research Institute in New Delhi, India. The experiment was designed as a split plot with two potassium values, 62.5 and 125 kg K ha^{-1}. The application of 62.5 kg K ha^{-1} in two equal splits (half at transplanting and half at maximum tillering) resulted in a significantly greater total number of tillers, dry matter accumulation, grain yield, and straw production.

2.10 Effects of K on grain filling

K supplementation enhanced the maximum and average filling rates of superior and inferior spikelets and optimized spikelet grain filling (Xu *et al.*, 2023). The K application altered spikelet filling and increased spikelet contribution rate (inferior spikelets outpaced superior spikelets)

(Lei *et al.,* 2015). The cause might be that K fertilizer altered rice photosynthesis (Weng *et al.,* 2007).

Marschner (2012) discovered that appropriate quantities of K can improve agricultural plant total dry mass accumulation under drought stress compared to lower K concentrations. These results might be attributed to stomatal control by K resulting in increased rates of photosynthesis. Additionally, K is required for the transfer of photo assimilates during root development.

According to Singh *et al.* (1990), potassium fertilizer played a key influence in producing high steady yields of crops. They also observed that hog manuring in conjunction with N and P application or N, P, and K application was an excellent combination, increasing N and P usage efficiency by 6 to 18% and 1 to 10%, respectively.

Kaisar *et al.* (2020), proclaimed that application of cow dung and K fertilizers, the potassium content of BRRI dhan48 grain and straw fluctuated greatly. The K concentration in rice grain ranged from 0.273 to 0.315% and in straw from 1.324 to 1.535%.

2.11 Fertilizer requirements under coastal soil

Mineral nutritional components play a range of tasks in plants, including being a constituent of the plant cell wall, aiding in the maintenance of osmotic relations and cell turgor pressure, transferring energy, participating in enzyme-catalyzed processes, and participating in reproduction (Pandey, 2018). Plants need the presence of 17 distinct elements in order to grow and develop (Pilon-Smits *et al.,* 2009).

In the southwestern coastal soil of Bangladesh, it is assumed that 70 kg ha^{-1} N (FRG, 2018), 6 to 12 kg ha^{-1} P (Ahmed, 2019) fertilizer is required for rice to survive. The response of potassium in coastal soil rice is still unknown but it is observed that potassium has a little bit slower response in other field crops and uptake also.

Farmer applies more or less than the judicious dosage for which potassium remains in the soil and soil tests have also proven this. Soils that are high in potassium do not need to be re-fertilized. So, it is still unknown how much potassium is required for a rice variety across the country. In this situation, the actual requirement of potassium needs to be determined.

2.12 Effects and requirements of Potassium on plants under coastal soil

The molar Na/Ca/K ratio of seawater is 47 while Na/Ca and Na/K ratios of 26 and 150 are possible in some coastal saline-sodic soils (Reyes *et al.,* 1983).

Devitt *et al.* (1981) found a significant inverse relationship between the K in plant leaves and the depth-weighted K in solution as well as between Na in leaves and K in leaves at harvest in wheat plants (*Triticum aestivum L.* 'Cajeme 71'). He also noticed that the product of K/Na in the soil solution and root length density, averaged over each depth increment measured, was the greatest predictor of the K/Na ratio detected in leaves at harvest (Devitt *et al.,* 1981).

The addition of Ca to the root environment with 40 mM (NaC1) salinity reduced the Na/Ca ratio, marginally increasing rice growth and K absorption (Kawasaki and Moritsugu, 1978). The nutritional status of K in plants is related to the molar ratio of Na/K in saline-sodic soil saturation extracts (Devitt *et al.,* 1981).

Delgado and Sánchez (1999) discovered that, in the apparent lack of salinity, K supply increased seedling biomass significantly, which tends to reflect what happens in the aerial part and root. This increase was greater in the stem than in the leaf.

Kibria *et al.* (2015) proclaimed that salinity reduced both salt-sensitive and salt-tolerant rice cultivars' growth and yield components, but potassium fertilizers increased them under saline situations. Salinity significantly reduced grain and straw yields in salt-sensitive and salt-tolerant rice varieties; Under salinity stress, the salt-tolerant cultivar (Binadhan-10) outperformed the salt-sensitive cultivar (BRRI dhan28) in grain production (Kibria *et al.,* 2015).

***K^+/Na^+ ratio in rice*:** Potassium fertilizer application raised the K^+/Na^+ ratio in rice during soil salinity in rice. The addition of potassium fertilizer improved the K^+/Na^+ ratio considerably (Kibria *et al.,* 2015).

Plant salt tolerance necessitates not only adaptation to Na toxicity but also the acquisition of copious K, the absorption of which by the plant cell is disrupted by high external Na concentrations (Zhang *et al.*, 2010).

The use of K to remove Na from the soil's exchange sites is required for the removal of exchangeable Na. There is mounting evidence that using K fertilizers lessens the negative effects of salt on a range of crops (Wakeel, 2013). As a result, crop output on saline soils might be improved by balanced fertilization, notably through efficient management of K fertilizer with selected high-yielding crop cultivars.

2.13 Potassium interaction with the uptake of other nutrients in saline soil

Kibria *et al.* (2015) found that Potash fertilizer use resulted in increased absorption of critical elements such as nitrogen, phosphorus, and sulfur in both salt-sensitive and salt-tolerant rice cultivars.

Safaa *et al.* (2013) discovered a similar finding, demonstrating that salinity stress reduced nutrient absorption rate and potassium fertilizer administration was useful in alleviating the salinity problem.

2.14 Relationship between grain filling and yield

The grain filling stage is an essential step in the development of rice production, and the spikelet filling condition directly influences the ultimate spikelet weight. The ultimate weight of the inferior spikelets can be raised by boosting non-structural carbohydrates in stems and leaves during the heading stage of rice and maximizing the formation of vascular bundles (Xu *et al.*, 2023).

K fertilizer may boost rice's 1,000-grain weight by promoting the accumulation and movement of non-structural carbohydrates (Zheng *et al.,* 2010). Ali *et al.* (2021) discovered a substantial positive relationship between spikelet filling rate and 1,000-grain weight.

The grain filling rates of superior and inferior spikelets were positively linked with 1,000-grain weight. As a result, boosting the spikelet grain filling rate is an efficient strategy to enhance the 1,000-grain weight (Xu *et al.*, 2023).

2.15 Research Area and potassium

With the green revolution, increasing cropping intensity and the adoption of high-yielding cultivars have resulted in soil K depletion. A recent soil test from 33 Indian states classified 41.1%, 29.3%, and 29.5% of soil samples as low, medium, or high in available K. This indicates that the rice crop reacts to K nutrition (Vijayakumar *et al.*, 2021).

Chowdhury and Bodiuzzaman (1992) observed that applying 0 kg, 50 kg, 100 kg, and 150 kg K and 60 kg S ha^{-1} to rice resulted in grain yields of 4.5 t ha^{-1}, 4.8 t ha^{-1}, and 4.9 t ha^{-1}, respectively.

Mineralogical composition, weathering of primary K-bearing minerals, chemical routes, and dynamic equilibrium between distinct K fractions all influence potassium (K) availability in soils. Nevertheless, K-fertilizer recommendations in South Asia are broad, which may have an impact on production and soil K-fertility status in rice-based systems (Timsina *et al.*, 2013).

Field studies were carried out in several agro-climatic zones of India to investigate the effect of split K treatment on rice. The use of K in two splits (basal and active tillering) resulted in improved grain production in Tamil Nadu and Orissa. Application in three divides produced the best results in Kerala, Punjab, Uttar Pradesh, and Himachal Pradesh. Poor N usage efficiency is frequent in lowland rice soils, providing the door to the development of novel N: K granules for use in lowland rice (Annadurai *et al.*, 2000).

Field trials in several agro-climatic areas of India revealed that split application of K boosted grain production in Tamil Nadu and Orissa, while it recorded the maximum yield in Kerala, Punjab, Uttar Pradesh, and Himachal Pradesh. In lowland rice soils, poor N usage efficiency is prevalent (Jalali-Moridani, and Amiri, 2014).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description of the experimental site, experimental period, climatic conditions, soil, crop or planting materials, seed collection, experimental land preparation, fertilizer management, crop growing procedure, general observation of the field, harvesting and post-harvesting data collection, and statistical analysis.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted in the farmer's field of Pankhali village, Dacope which is 30 km away from Khulna University. The field experiment was conducted in Agro-ecological Zone (AEZ) 13, i.e., Ganges Tidal Floodplain and (22°38'00"N latitude and 89°30'12" E longitudes) at an elevation of 3 m from sea level.

Figure 1. Map view of experimental area, located at Dacope Upazila, Khulna, Bangladesh

Dacope is bounded on the north by Batiaghata Upazila, on the south by the Pashur River, on the east by Rampal and Mongla Upazilas, and on the west by Paikgachha and Koyra Upazilas. The Sundarbans are located in the southern part of this Upazila. The major rivers in this region are the Sibsa, Bhadra, Chunkuri, Dhaki and Jhapjhopia (Banglapedia, 2021).

3.1.2 Experimental period

The experiment was conducted in the *Aus* season (April-July) 2022. Seeds were broadcasted at 15th May, 2022 and harvesting was done at 3rd September, 2022.

3.1.3 Weather conditions during experiment

Details of the meteorological data of air temperature and rainfall during the period of the experiment were collected from the meteorological station, Khulna Regional Weather Office, Khulna. The experimental field was characterized by a sub-tropical climate with moderately high temperature and high rainfall mainly concentrated during the *kharif* II season (April to October) (Bell *et al.*, 2019).

3.1.4 Soil characteristics

The experimental field was medium-high land with clay-dominated soil (soil pH: 6.5-7.0), having minerals dominating mica and smectite (FRG, 2018). The organic matter concentration was 2.4% (medium). The salinity of soil and river water of the location increases as the dry period progresses and reaches its peak at the end of May.

3.2 Experimental design and treatment

The experiment was laid out in a Randomized Complete Block Design (RCBD) having six treatments with three replications. The number of plots was 18. The size of each plot was 3 m (north-south) x 1.5 m (east-west) = 4.5 m^2. The spacing between replications was 1.0 m, and the interval between plots was 0.5 m. Six potassium (K) doses were the treatments as follows: -

Potassium rates were:

K_0- No potassium added

K_1- (10 kg K ha^{-1})

K_2- (20 kg K ha^{-1})

K_3- (30 kg K ha^{-1})

K_4- (40 kg K ha^{-1}) and

K_5- (50 kg K ha^{-1}).

3.3 Preparation of experimental field

The experimental land was ploughed by a power tiller three times and was leveled carefully to get a well puddled soil. All kinds of weeds and residues of previous crop were removed from the field. The experiment was set according to the Randomized Complete Block Design (RCBD) with three replications.

3.4 Fertilizer management

Other fertilizers such as nitrogen (72 kg ha^{-1}), phosphorus (9 kg ha^{-1}), sulfur (3 kg ha^{-1}), zinc (1 kg ha^{-1}) except K were applied according to the recommendation of the FRG (2018) for the T. *Aus* rice in the AEZ 13. Nitrogen, phosphorus, and potassium were applied in the form of urea, triple superphosphate (TSP) and muriate of potash (MoP). All the fertilizers except urea were applied during final land preparation. Urea was applied as top dressed in three equal splits at 10, 30 and 45 days after sowing (DAS). Again, calcium and zinc were applied in the form of gypsum and zinc sulphate. Fertilizers such as TSP-10.5 kg ha^{-1}, MoP-36 kg ha^{-1}, Gypsum-7 kg ha^{-1} and ZnSO4 -1.2 kg ha^{-1} were applied (Sumona *et al.*, 2022).

3.5 Planting material

BRRI dhan48 is a high-yielding rice variety was used as plant material for the present study. Seed was collected from Bangladesh Agricultural Development Corporation (BADC) regional station, Fultola, Khulna.

3.6 Seed sowing

The seeds were sown on 15th May, 2022 after the start of rain and the crop was grown entirely on seasonal rainfall, no irrigation was applied.

3.7 Care after broadcasted seedling

After the establishment of seedlings, intercultural operations such as weeding, urea split application, were done. Hand weeding was done firstly at field preparation and second was done 15 days after emergence.

3.8 Plant protection

The field was observed from time to time to detect the visual difference among the treatment from plot to plot and replication to replication. Observation of disease infestation, insect and pest infestation was done to keep the field crops safe for better growth of the crop to get maximum yield. No bacterial and fungal disease was observed. No insect and pest attacks were found.

3.9 Harvesting and post-harvest operation

The crop was harvested on 3rd September, 2022 when 80-90% of the grains had turned golden yellow in color. An area of 0.5 sqm was harvested per plot for calculating grain yield. Threshing was carried out manually. The grains were cleaned and dried under sunlight. The straw was oven dried at 60°C -65°C. Finally, grain (at 14% moisture content) and straw yields of each treatment was determined and converted to t ha^{-1}.

3.10 Data collection, recording and calculation

Data on the following growth and yield parameters were collected. The data on plant height was collected from the randomly selected ten plants from each plot at 60, 75 days after emergence (DAE) and at harvest. Other data was collected on SPAD (Soil Plant Analysis Development) value, effective tiller $hill^{-1}$, panicle length, 1000- grains weight and grain yield.

3.10.1 Crop growth parameters

3.10.1.1 Plant height (cm)

The height of 5 plants was recorded at the time of 60, 75 DAE and at harvest. The height was measured from the ground level to the tip of the tiller.

3.10.1.2 SPAD (Soil Plant Analysis Development) value

SPAD value was measured using a non-destructive SPAD meter that exposes a small part of the leaf to light and calculates the amount of unabsorbed chlorophyll throughout the photosynthetic process. It was measured at 60 DAE and 75 DAE from each plot.

3.10.2 Yield contributing parameters

3.10.2.1 Effective tillers (m^{-2})

The total number of effective tillers per 1 square meter was counted during harvesting time.

3.10.2.2 Panicle length (cm)

Panicle length was taken from the basal node of the rachis to the apex of each panicle. Each observation was an average of 10 panicles.

3.10.2.3 Number of grains panicle^{-1}

On the basis of grain yield spikelet, the total number of grains was collected from randomly selected 10 plants in a plot, and the average number of grains panicle^{-1} was recorded.

3.10.2.4 1000- grains weight (g)

1000 clean and fully developed dried grains were collected from each plot separately and weighed by an electric balance and the weight was adjusted at a 14% moisture level.

3.10.3 Yield parameters

3.10.3.1 Grain yield (t ha^{-1})

Grain yield was obtained from the 0.5 sqm of each plot. The weight was adjusted to a 14% moisture level. The weight of grains of each plot was converted to t ha^{-1}.

3.11 Statistical analysis of data

Using 'Statistix 10', the gathered, computed, and recorded data on various parameters were assembled and statistically analyzed using analysis of variance procedures (one-way ANOVA) following RCBD. The significant differences across treatment means were compared using the least significant difference (LSD) test at the 5% level of significance.

CHAPTER IV

RESULTS

The result of the experiment is presented in this chapter by evaluating the growth, yield attributes and yield of broadcast *Aus* rice (BRRI dhan48) in response to different potassium rates.

4.1 Soil

Soil potassium status was high (0.35 meq 100 g soil^{-1}) in the selected area. The general features of the study soil are presented in Table 3.

Table 3. Chemical properties of the experimental soil in Pankhali village of Dacope Upazila, Khulna. Critical limit and nutrient interpretations of different nutrients were taken from FRG (2018).

	N (%)	P (µg/g soil)	K (meq/100 g soil)	Cu (µg/g soil)	Zn (µg/g soil)	B (µg/g soil)
Soil test value	0.124	31.34	0.35	107.42	1.51	1.16
Nutrient status	Low	High	High	Very high	High	Very high
Critical limit	0.12	5.0	0.12	0.2	0.6	0.2

4.2 Temperature (°C)

The minimum temperature ranges from 21.5 °C to 29.5 °C and the maximum temperature ranges from 26.4 °C to 37.6 °C in the experimental area (Figure 2).

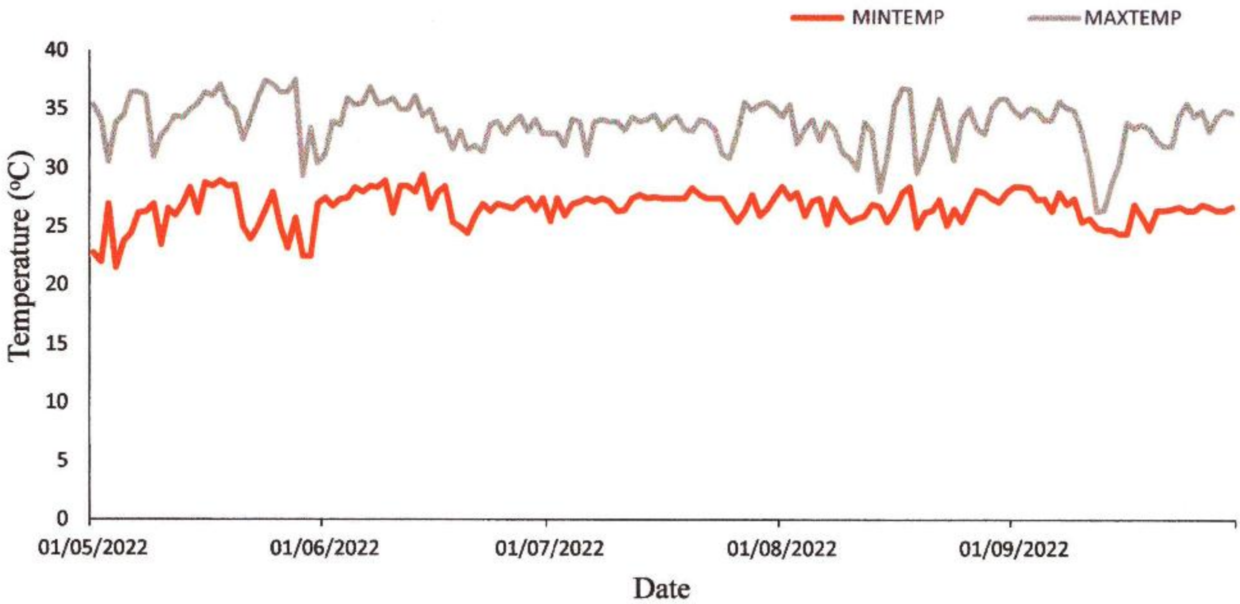

Figure 2. Maximum and minimum temperature during the growing period (May-September) in the experimental area (Pankhali, Dacope, Khulna)

4.3 Rainfall (mm)

The southwest coastal region is experiencing an increase in both the number of rainy days per year and the maximum number of consecutive rainy days (Mondal *et al.,* 2013). The measurement of rainfall during the experiment shows that there was sufficient rainfall during the experiment period (May to early September 2022) (Figure 3). The maximum rainfall was 146 mm to 1 mm minimum and there was considerable rainfall occurred just before the start of the experiment.

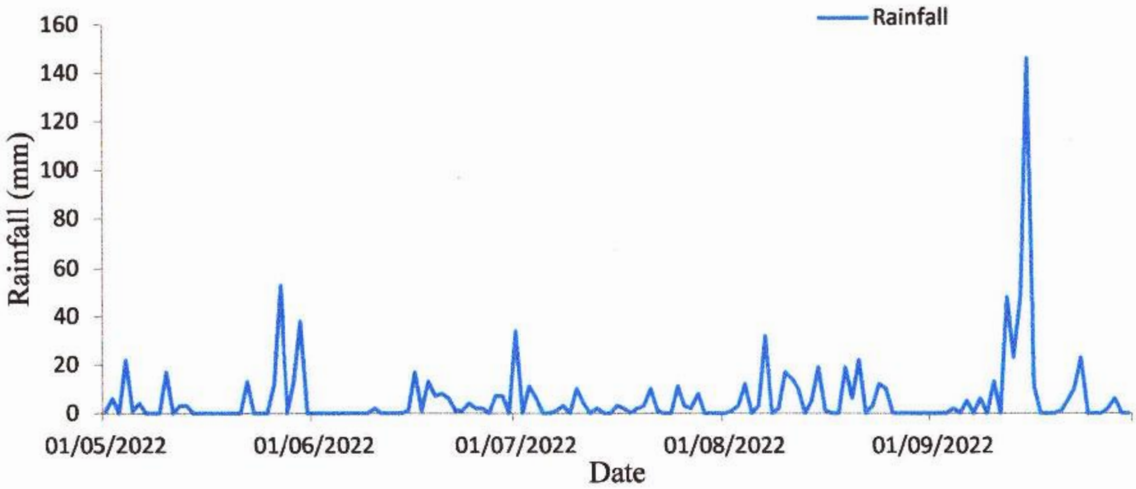

Figure 3. Rainfall pattern during the growing period (May- September) in the experimental area (Pankhali, Dacope, Khulna)

4.4 Plant height (cm)

Plant height was statistically non-significant among the potassium rates at 60 and 75 DAE (Figure 4). Potassium addition has no effect at a particular DAE on plant height but with the increase of plant age the height was more at 75 DAE.

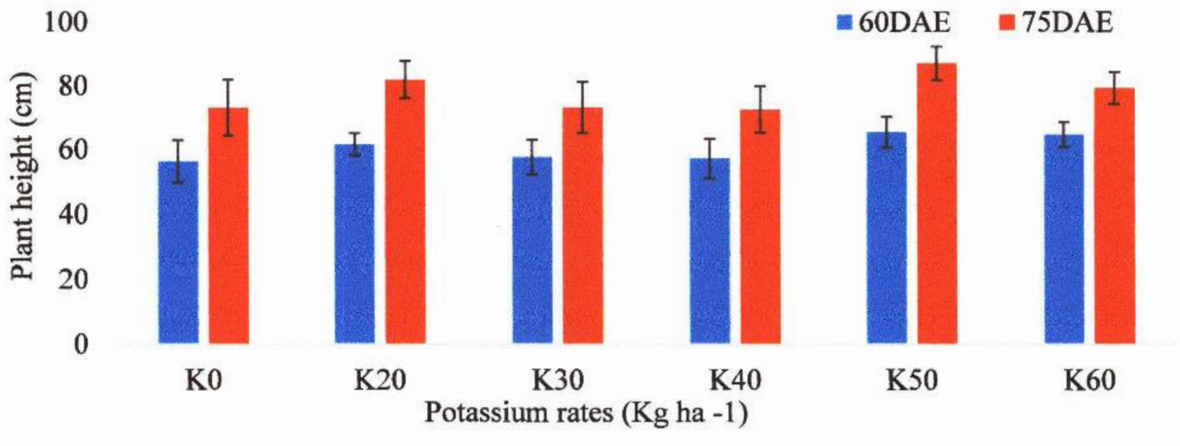

Figure 4. Effect of potassium rate on plant height of B. *Aus* rice (BRRI dhan48) in southwestern coastal region of Bangladesh (Pankhali, Dacope, Khulna)

4.5 SPAD value

SPAD meter reading was statistically non-significant among the potassium rates at different DAE (Figure 5). The observed SPAD meter reading was numerically the highest (37.63) at 60 Kg ha^{-1} potassium rate and the numerical the lowest (35.10) was found in 20 Kg ha^{-1} potassium rate, respectively, at 60 DAE.

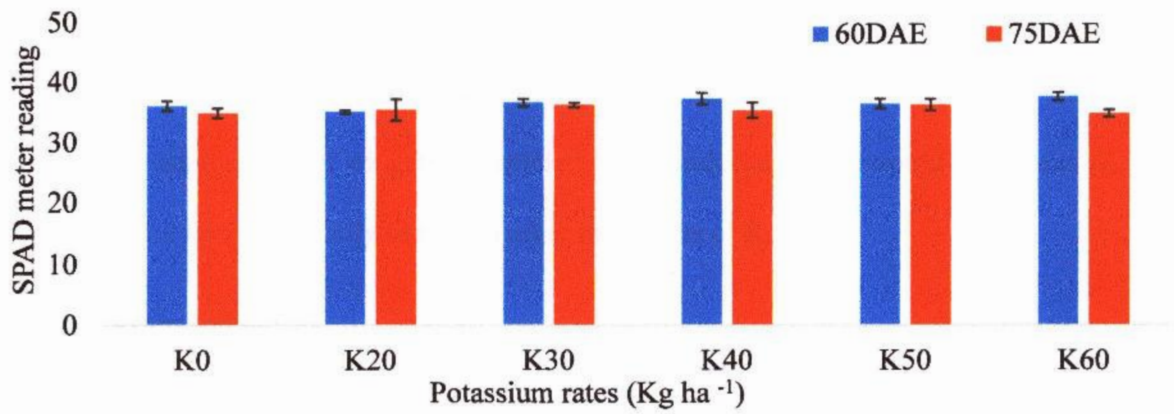

Figure 5. Effect of potassium rate on SPAD meter reading variation of B. *Aus* rice (BRRI dhan48) in coastal soil of southwestern Bangladesh

4.6 Effective tillers (m^{-2})

Application of different rates of potassium had no significant effect on number of panicle m^{-2} (Table 4). The findings showed an increasing trend of effective tillers m^{-2} with the increase in potassium doses. However, numerically it was recorded that 60 kg K ha^{-1} (K_{60}) produced the maximum number (353.3) of panicles m^{-2} and was statistically similar to all other K rates including the zero added K.

4.7 Panicle length (cm)

No significant variation was found regarding panicle length due to different potassium doses

4.10 Grain yield (t ha^{-1})

Grain yield was also statistically non-significant among the potassium rates (Figure 6). Numerically the maximum grain yield (4.49 t ha^{-1}) was recorded from 30 Kg ha^{-1} (K_{30}) which showed statistically similar results with 60 kg K ha^{-1} (K_{60}) and 40 kg K ha^{-1} (K_{40}) whereas the numerical minimum value (3.83 t ha^{-1}) was found in g 0 Kg ha $^{-1}$ (K_0) which was 85% of the maximum yield that obtained in 30, 40, 50 and 60 kg K ha^{-1}.

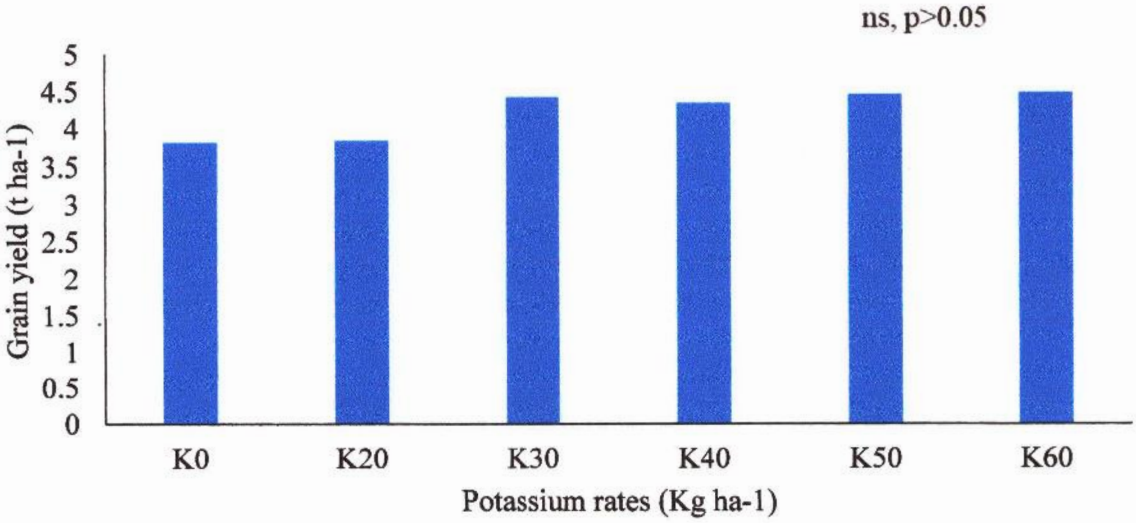

Figure 6. Effect of potassium rate on grain yield of B. *Aus* rice (BRRI dhan48) in coastal soil of southwestern Bangladesh (Pankhali, Dacope, Khulna)

CHAPTER V

DISCUSSION

The addition of K fertilizer from 0 to 60 kg ha^{-1} had negligible impact on the yield of B. *Aus* rice on most of the studied parameters including yield attributes (panicle length, number of grains $panicle^{-1}$,1000 grain weight and effective tillers) and grain yield. However, the treatment 'K_{30}' that received 30 kg K ha^{-1} resulted in the numerical highest grain yield, although it was not statistically significant among the six potassium rates. Potassium has an important role in starch synthesis and grain development (Mengal, 1982) thus its adequate supply showed a positive effect in producing heavier rice grain (Niazi *et al.,* 1992). The positive influence of K on all yield-contributing characters of rice plants contributes to higher yield with a higher K dose. K helps rice grain and straw gain large volume and heavier weight, leading to an increase in yield (Kondo *et al.,* 2001). In the current study the soil K was high (FRG, 2018) which might have supplied the K requirement for rice. Hence, no significant variation was found.

Hasegawa (2003) reported that rice cultivars with higher dry matter tend to produce higher yields. Among the different K levels tested, the highest grain yield was obtained from 30 kg K ha^{-1} (K_{30}) which was not significantly different from other K treatments. In contrast, the lowest grain yield was observed in 0 kg K ha^{-1} (K_0) treatment. The soil analysis report of this field revealed that soil contained 0.35% K (1-15 cm soil depth) which is designated as high amount of K in soil for AEZ-13 (FRG, 2018). In Bangladesh, the fertilizer recommendation is based solely on the soil test and not on plant response. While the potassium recommendation for T. *Aus* rice is available in FRG 2018, it is not available for B. *Aus* rice in the southwestern coastal zone (FRG, 2018). As per FRG (2018), the recommended K rate for T. *Aman* in the fallow-fallow-T. *Aman* cropping pattern in saline soil of AEZ -13 is 41-60 kg K ha^{-1}. Additionally, T. *Aus* is not suitable for B. *Aus* in the same area due to high saline water that hinders seedling raising in the seedbed and land preparation for transplanting.

To summarize, it is feasible to cultivate *Aus* rice during the Kharif-1 season in the southwest coastal region of Bangladesh. Temperatures in southwest coastal Bangladesh show a general increasing trend at seasonal and monthly time scales (Mondal *et al.,* 2013). The seeds should be broadcasted right after the start of the summer rainfall, with no application of K. But without application of K for several years, the negative K balance will be the result. Thus, a maintenance dose of K should be applied for the soil health. Further research is necessary to determine the K requirement of B. *Aus* in other areas of the southwestern region, as well as more similar research is needed in this agroecological zone (AEZ -13) of Bangladesh.

CHAPTER-VI

SUMMARY AND CONCLUSION

The experiment on B. *Aus* rice was conducted in the *Aus* season (April-July) 2022. The land was prepared just after the start of early summer rainfall and the seeds were broadcasted at 15th May, 2022 in the farmer's field of Pankhali village, Dacope, Khulna. The crop was harvested on 3 September, 2022 with a view to evaluate the effect of K on yield and investigate the optimum rate of nitrogen for realizing the highest grain yield of an HYV broadcasted *Aus* rice BRRI dhan48. The experiment involved six distinct potassium treatments as K_0 (0 kg K ha^{-1}), K_{20} (20 kg K ha^{-1}), K_{30} (30 kg K ha^{-1}), K_{40} (40 kg K ha^{-1}), K_{50} (50 kg K ha^{-1}) and K_{60} (60 kg K ha^{-1}) with three replications.

As there was no recommended K rate for broadcast *Aus* rice, a range of K rates was taken including the recommended K rates for T. *Aus* rice (40 kg ha^{-1}). There was no significant difference of grain yield due to K rate variations. In zero added K treatment, the grain yield was found 3.83 t ha^{-1} which was fluctuated between 3.83 to 4.49 t ha^{-1} in the other K treatments but they were statistically similar. Almost similar grain yield was produced in K_{30} (4.49 t ha^{-1}), K_{40} (4.35 t ha^{-1}), K_{50} (4.47 t ha^{-1}) and K_{60} (4.49 t ha^{-1}) of the recommended K (40 kg ha^{-1}, for T. *Aus*) (Figure 6). At zero applied K, the grain yield reduced numerically but not statistically. All yield parameters were non-significant in response to K rates (Table 4). The grain yield response to applied K was more or less similar.

The omission of K had little or no effect on the yield of *Aus* rice. In other crops (sunflower, wheat, T. *Aman*) application of K had also little or no effect on yield. It was found that yield variation in the crops mentioned was mainly due to N variation. Hence, in the FRG 2018, the amount of K recommendation seems to overdose in a range of crops in the SW coastal area. Although crops had less response to K, at least a maintenance dose for soil health need to be advised and that could be 20-30 kg ha^{-1}. Thus, the suggestion of K recommendation for broadcast *Aus* could be 20 to 30 kg K ha^{-1} for the SW coastal Bangladesh instead of 40 kg K ha^{-1} in the current FRG (2018).

Recommendations

I. This is a single year and single location trial so more research is needed in this Agro-ecological zone (AEZ -13) of Bangladesh for the conformity of the K rate for B. *Aus* rice.

II. It is suggested that future researchers should investigate how to utilize potassium fertilizer wisely in order to get maximum yield with improvements in the growth and yield of BRRI dhan48.

III. Additionally, it is suggested that agricultural extension services to conduct mass campaigns to increase awareness of the judicious use of K fertilizers for B. *Aus* in the coastal soil of southwestern Bangladesh.

CHAPTER-VIII

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