Combined Effect of NPK on Grain Yield of Broadcast *Aus* Rice in the Coastal Soil of Southwestern Bangladesh

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TO

MY BELOVED PARENTS

Combined Effect of NPK on Grain Yield of Broadcast *Aus* Rice in the Coastal Soil of Southwestern Bangladesh

ABSTRACT

The yield potentiality of rice mostly depends on the judicious management and appropriate combination of applied nutrient. In southwestern region of Bangladesh broadcasting (B) *Aus* rice has been emerging as a new cultivation technique instead of Transplanting (T) but the nutrient measurement of this rice was not determined. Therefore, the field experiment was carried out with ten combinations of nitrogen (N), phosphorus (P) and potassium (K). The N, P and K rates were taken from the transplanted (T) *Aus* rice @ 70-10-55 kg ha^{-1} as 100% of each N, P and K, respectively, and those doses were varied as per cent of full rates as 100%, 75%, 50% and 25%. There was treatment with no added N, P and K. The treatments were (N-P-K kg ha^{-1}) 0-0-0, 0-100-100, 100-0-0, 100-25-100,100-100-100, 100-100-25, 100-100-75, 100-50-100, 100-100-50 and 100-75-100 per cent of recommended N, P, K to evaluate the effect NPK combination of growth, yield attributes and yield of *Aus* rice (BRRI dhan48). The NPK combination of @100-100-100 kg ha^{-1}significantly produced ($p< 0.01$) the highest plant height, tiller number, panicle length, number of filled grain $panicle^{-1}$,1000 grain weight, grain yield, straw yield, biological yield, SPAD value, effective tiller except unfilled grains (@ (100-0-0 kg ha^{-1}) and lowest was produced from no NPK added plot. The results revealed that N highly significantly affected the growth, yield attributes and yield of rice while P and K had minor effect on the measured parameters. N was found the main yield determinant. Yield reduction was observed very low due to the omission of P and K, respectively, with the similar rate of N. When N omitted the yield decreased drastically (~41%) but omission of P and K had little influence on yield. This might be due to the low soil N content and moderate to high P and K content in the soils of this region. The highest grain yield was obtained with an NPK combination of @100%-100%-100% of recommended rate which increased

grain yield by 9.23-83.58% over other treatments. From the findings of this study, we concluded that NPK @ 100-100-100 kg ha^{-1} is the suitable combination for the broadcasting cultivation of BRRI dhan48 in the coastal soils of southwestern Bangladesh.

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The Authors

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CHAPTER-I

INTRODUCTION

Rice is the staple cereal in Bangladesh which is grown in pre-monsoon (*Aus*) (April to June), monsoon (Aman) (wet season, July to November) and Boro (dry season irrigated, December to April) seasons (Islam et al., 2015). Several hurdles, such as increasing population, decreasing resources (shrinking net cropped area, scarcity of water for irrigation), increasing climate vulnerability and pressure on soil fertility are hindering in achieving the target of rice production. Among many factors, adequate use of essential primary nutrient elements greatly influences rice growth and development and thus yield and productivity. On the other hand, with the development of improved rice varieties as well as better soil and fertilizer management approaches, rice yield is generally increasing in Bangladesh and other rice growing countries over the years. As a consequence, Nitrogen (N), phosphorus (P) and potassium (K) nutrient removal is increasing gradually from the soil (Islam et al., 2016).

Plant nutrients are crucial for a plant's growth and development. Plants require higher amount of the macronutrients nitrogen (N), phosphorus (P), and potassium (K) than the other macronutrients. Fertilizers are excellent source to get nutrients. Emergence, tillering, panicle initiation, booting, heading, and maturation are all crucial stages for rice. These stages are more sensitive, and the crop should be protected from nutritional stress in these stages. To obtain high yields, rice crop requires the fulfillment of NPK. In the farmer's practice, there are several options for NPK fertilizers. On the other hand, nutrient requirements vary greatly depending on climate and soil conditions (Yin et al., 2019). To produce more rice yields, it's important to apply fertilizers at the optimum rate, right time and in the right way.

Nitrogen fertilization, crucial for rice plants, enhances photosynthesis, spikelet formation, biomass accumulation, and root development (Jahan et al., 2020; Fageria and Santos, 2014). Applying nitrogen during the panicle initiation stage is preferable (Mazid Miah et al., 2016). Nitrogen deficit results in leaf loss, chlorosis, and decreased grain yields (Chen et al., 2014; Zhang et al., 2015). Phosphorus is essential for improving crop quality, seed production, and spikelet sterility (Rice Knowledge Bank Website, 2020). Phosphorus absorption is limited (Hye et al., 2019), and deficiency leads to stunted growth, shorter leaves, reduced tillering, and thin stems. Potassium influences plant growth, metabolism, and disease resistance (Wang et al., 2013). Potash fertilizer enhances potassium uptake and reduces sodium absorption in saline soil. Potassium deficiency decreases shoot and root potassium content and increases antioxidant enzyme activity in rice plants (Liu et al., 2013).

Rice production in Bangladesh needs to be increased to feed 215.4 million people in 2050 (Kabir et al., 2015). This can be done in two ways: horizontal expansion of rice growing area and increasing the yield, or both (Hasan et al., 2015). The little or no scope of horizontal expansion for increasing rice except the coastal saline zone, e.g., in the southwestern (SW) region of Bangladesh. In this area the cultivable land remains fallow during the dry summer season (April to July) when irrigated and transplanted *Aus* rice is grown in many parts of the country with a NPK rate @ 67-10-41 kg ha-1(BRRI., 2020). There is no fertilizer recommendation for B. *Aus* rice. Due to scarcity of fresh irrigation water and constraints for raising rice seedling, transplanting is not feasible (Sumona 2022). Based on early summer rain (end of May and early June), direct seeding of *Aus* rice seed in the main field just after first summer rain can be possible (Lima 2019; Sumona 2022).

After emergence, in the subsequent stages, *Aus* rice growth continues as rainfed, without any irrigation. As broadcast dry seeding *Aus* has been emerging as a new crop in the SW coastal region, its response to different combinations of the primary nutrient elements (N, P and K) has not been investigated. Thus, the experiment was conducted in the farmers' field of typical SW region to investigate the (combination of NPK) effect on *Aus* rice yield. Judicious nutrient management of the nutrients may improve the productivity of the *Aus* rice in this region. Farmers will get a second rice (other is transplanted Aman) which will improve their livelihood and strengthen the food security of the region and the country.

OBJECTIVES

- To investigate the yield response of Broadcasted *Aus* rice with the various NPK combinations.
- To find out the suitable rates of NPK for Broadcasted *Aus* rice in the experimental area of southwestern coastal zone.

CHAPTER-II

REVIEW OF LITERATURE

3.1 Worldwide rice production

Oryza sativa L. is a staple food for almost 3.5 billion people around the world (IRRI, 2013). Rice is grown and consumed in greater quantities in Asia than in other parts of the world. Rice consumption has been steadily increasing across the Caribbean and Latin American regions, according to reports (IRRI, 2013).

Rice is directly related with food security and political stability in the population of underdeveloped countries, with an estimated 870 million people suffering from chronic malnutrition worldwide (FAO, 2012). Rice provides more than half of a person's daily caloric intake and a significant portion of their protein intake for Asia's 520 million poor people. Rice consumption among urban inhabitants in Sub-Saharan Africa has gradually increased, with per capita consumption having doubled since 1970 (IRRI, 2013).

Rice is an important source of nutrition for people in the Asia-Pacific area, sections of Latin America and the Caribbean, and, increasingly, Africa (FAO, 2006). Rice production is the principal source of income and employment for more than 200 million households in underdeveloped countries (FAO, 2004).

3.2 Rice production in Bangladesh

Rice production is the foundation of Bangladesh's agriculture; in this country, as in many others, 'food security' is almost entirely dependent on 'rice security' (Brolley, 2015). Rice production alone accounts for around 4.5 percent of GDP (BBS, 2020).

According to the people of Bangladesh's food habits, 'rice security' should also include 'nutrition security.' Rice is not only a carbohydrate-rich food in this country, but it also supplies protein, minerals, and health advantages. Rice also contains antioxidants that help to reduce oxidative stress, prevent cancer, diabetes issues, and cardiovascular difficulties (Shozib et al., 2020).

Currently, the country produces around 33.0 million tons of food, enough to feed 160 million people (Barmon and Chaudhury, 2012) . Bangladesh's rice output might be 35.5 million tons this year, according to the US Department of Agriculture's November grain prediction for FY 2021-22, despite a low harvest in the *Aus* season. Rice output was over 36. 3 million tons in FY21, according to preliminary estimates from the Bangladesh Bureau of Statistics (BBS). According to the most recent USDA prediction, rice yields in FY22 could drop by 0.8 million tones. According to the latest USDA study, rice output in Bangladesh for marketing year (MY) 2021-22 might be 35.5 million tones on 11.42 million hectares, which is 2.2 percent and 2.1 percent lower than the USDA's official prediction (The Financial Express, 2022).

3.3. Rice production in southwestern Bangladesh

Khorip is the dominant crop season in the region. The average production of rice during khorip season is 4,232 kg ha -1 in low saline areas, whereas, it is 3,760 kg ha -1 and 2,663 kg ha -1 for moderate and high saline areas, respectively. Salinity intrusion negatively influences farm profitability as well as farm performance. If the salinity of high saline area can be reduced to the threshold level, farmers will gain about 685 US$ ha -1 from increased rice yield. Salinity level needs to be controlled for realizing the benefits from an increase in production. Drainage, fresh water management for irrigation in time of dry season and spreading salt tolerant rice varieties in saline prone area are the controlling measures against salinity intrusion (Ahmed and Haider, 2014). According to Sarwar and Khan (2007), both water and soil salinity along the coast increase with the rise in sea level. Haque (2006) shows that fertility status of saline soils ranges from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. Ali (2006) states that salinity ingress has a negative impaction rice ecosystem and increased soil salinity depletes soil Ca, K, Mg, and organic C content. Moormann and Breemen (1978) demonstrate that crop yield decreased by 50 percent when soil salinity level (EC values) reaches to 6-10 dSm-1. Under the said circum- stances, this study attempts to quantify the effect of salinity on rice production in the south-west region of Bangladesh.

3.4. Cropping pattern of southwestern Bangladesh

A slight change was observed regarding climate resilient cropping pattern over the last 30 years in this area. About 30 years ago, five cropping patterns were practiced, only one pattern (Fallow-Fallow-T. Aman) was found climate resilient. About 20 years ago, 11 cropping patterns were practiced, 5 patterns (Fallow-Fallow-T. Aman, Boro-Fallow-T. Aman, Boro-Gher (vegetables)-T. Aman, Boro-Gher (vegetables)-Fallow and Fallow-Gher (vegetables)-T. Aman) were found climate resilient. About 10 years ago, 11 cropping patterns were practiced, 7 patterns (Sesame-Fallow-T. Aman, BoroFallow-T. Aman, Boro-Gher (vegetables)-Fallow, Fallow-FallowT.Aman, Boro-Jute-T. Aman, Boro-Gher (vegetables)-T. Aman and Fallow-Gher (vegetables)-T. Aman) were found climate resilient. At present, 14 cropping patterns are being practiced. Out of which, six patterns are climate resilient (Sultana. et al. 2020).

3.5. NPK fertilizer requirement in plant body

Plants require 17 different elements in order to grow and develop (Pilon-Smits et al., 2009). Mineral nutritional elements have a variety of roles in plants, including constituent of plant cell wall, assists in osmotic relation and cell turgor pressure maintenance, energy transfer, participation in enzyme catalyzed activities, and participation in reproduction (Pandey, 2018).

Plants absorbed nitrogen in two different forms: nitrate (NO_3^- absorbed during the dry season) and ammonium (NH_4^+ absorbed during the wet season) (Abbasi et al., 2017). Microbes fix nitrogen from the atmosphere as ammonium ion (NH_4^+), which is subsequently oxidized into nitrate in a sequential process. For eukaryotic primary producers, this oxidized nitrogen is a significant source of nitrogen (Zerkle and Mikhail, 2017). Nitrogen is found in many cellular macromolecules, including chlorophyll, nucleic acids, proteins, and plant growth regulators (Nguyen et al., 2015).

Phosphorus, which accounts for up to 0.2 percent of plant dry weight, is another vital element for plant development and growth (Alori et al., 2017). During plant growth and development, it is essential for membrane formation and stability, nucleic acid synthesis, energy metabolism, and other critical physiological and biological activities (Hasan et al., 2016).

Potassium is a necessary element for plant development and metabolism, as it affects several biochemical and physiological processes (Wang et al., 2013). It performs critical functions related to cell expansion, turgor generation enzyme activation, osmotic adjustment, regulation of membrane electric potential and p^H homeostasis (Ragel et al., 2019).

3.6 Role and effect of NPK in rice production

Nitrogen is required for rice development and production as a component of amino acid and protein building blocks, nucleic acids, and chlorophyll. In addition to tiller number, spikelet number, panicle length, plant height and length, the volume of nitrogen used in rice indicated the ascribing qualities for yield and yield, as well as tiller number, spikelet number, panicle length, plant height and length (Dobermann and Fairhust, 2000). Leaching, volatilization, de-nitrification, and other losses of nitrogen to the soil are possible, thus appropriate management is required for maximum output and successful use under various cultivation circumstances, such as lowland, upland, and so on. Plants can absorb nitrogen in the form of NO_3^- and NH_4^+ ions (Shrestha et al., 2020).

Rice's root development, ripening, early flowering, and tolerance to various biotic and abiotic challenges are all dependent on phosphorus. Its absence will result in rice maturation delays and higher disease susceptibility (Fageria et al., 2003). Rice began to accumulate dry matter throughout the tillering phase, and phosphorus deficit manifested itself as stunting, erecting dark green leaves (Marschner, 1995). Rice maturity may be delayed by a week or two due to phosphorus deficit (Fageria, 1980). Phosphorus nutritional absorption by rice is dependent on the soil's potential and desorption and deficient features, as well as little and little reaction to major and minor nutrients such as potash, nitrogen, and zinc via rice in the soil (Roy and De Datta, 1985).

Potassium is required for root development, plant vigor, decreasing lodging, stimulating cell division, supplying osmotic pull, neutralizing organic acid, and increasing seed resilience to pests and diseases, as well as aiding to sustain metabolism. Rice contains K^+, which is one of the most important limiting nutrients after nitrogen. It's especially important to keep an eye on levels in the lignification of vascular bundles while they're wet. The appropriate use of potassium is linked to the lignification of sclerenchyma cells, as well as vascular bundles and panicle, which improve lodging resistance (Kong et al., 2014). Interveinal chlorosis and margins of the bottom leaf commencing at the tip of the leaf, which are characteristic of N-deficiency, but with minimal or no reduced tillering, stunted look, and higher dark green leaves are typical deficit indicators of K in rice (Fageria et al., 2003). The disease tungro appears in field areas and typically has more defined orange and yellow leaves with stunting appearance. K signs of deficiency in the rice leaf may be ambiguous with the disease tungro, but tungro appears in field areas and typically has more

3.7.1 Salinity status of the study area

The study area is much saline prone, but we sew seeds after the heavy rainfall as a result the salt of the top soil get diluted. So here, we did not include the soil salinity status. Figure 1. Shows the gradual increment of salinity in the coastal area where 833 hectare land affected in 1973 and increase to 1056 hectare in 2009. In figure 2. It is shown that the southwestern part of Bangladesh has several times more salt affected area than southeastern part.

Figure 3. shows the soil salinity class from 1973 to 2009 where in every class salinity is increased several time than 2009.

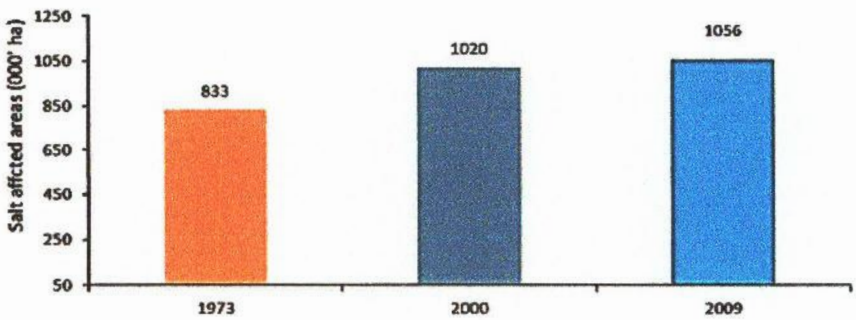

Figure 1. Land area ('000' ha) affected by salinity in the coastal areas of Bangladesh from 1973 to 2009 (SRDI, 2010)

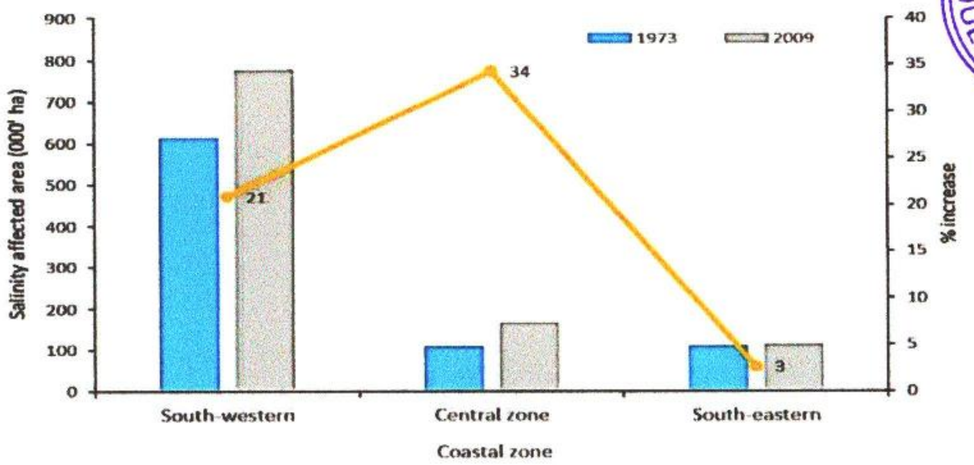

Figure 2. Trends of salinity-affected land areas in different coastal regions of Bangladesh (SRDI, 2010)

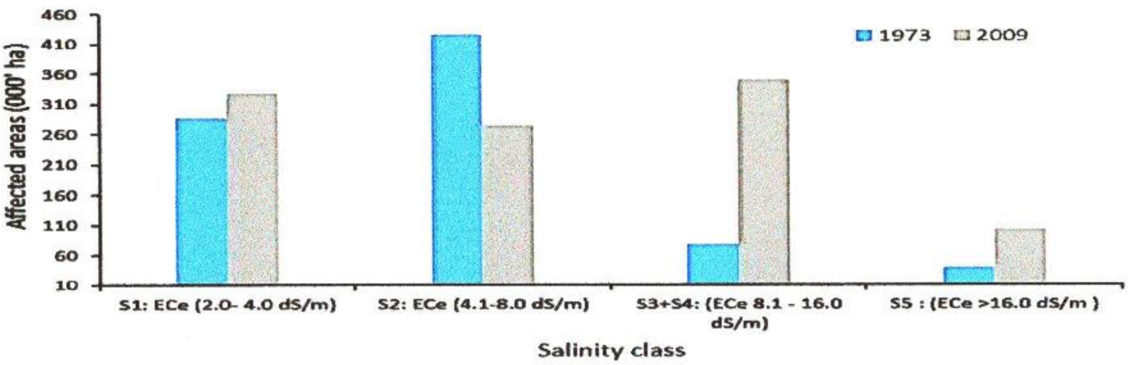

Figure 3. Salt-affected land areas from 1973 to 2009 categorized according to soil salinity class (SRDI, 2010)

CHAPTER- III

MATERIALS AND METHOD

The experiment was conducted to determine how NPK affects the growth and yield of the HYV Broadcasted *Aus* rice variety BRRI dhan48. This section contains a summary of the location, climate, soil, crop, experimental design, treatment, cultural operations, data collection and statistical analysis of the data acquired.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted in the farmer's field of Pankhali village, Dacope under Khulna district (Latitude of 22° 48.95' N and longitude of 89° 34.09' E) and it is 26 km away from Khulna University Campus. The experimental site was located under the agro-ecological zone 13 (AEZ-13) which is Ganges Tidal Floodplain.

3.1.2 Period of experiment

The experiment took place in late *Aus* season (May- August). Broadcasting of seed was done at 15.05.22 and harvesting was done at 06.08.22.

3.1.3 Soil

The experiment was conducted in a medium low land with clay type soil.

3.1.4 Climate

The experimental field is located within the Ganges Tidal Floodplain agro-ecological zone and is low-lying, with an elevation of 2–3 m above mean sea level (Paul et al. 2020). This region has a subtropical climate, with an average annual rainfall of 1800 mm, with 80% of that falling during the rainy season. The weather is cold and dry from November to February, while it is hot and humid from March to June (Paul et al., 2021).

3.1.5 Planting Material

BRRI dhan48 is a high yielding variety of aus season was used as plant material. The seed of BRRI dhan48 was collected from Bangladesh Agricultural Development Corporation (BADC) regional station, Phultola, Khulna.

3.2 Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD). The size of each plot was 4 m (north-south) x 2.5 m (east-west) = 10 m^2. The spacing between replications was 1.0 m, and the interval between plots was 0.5 m. Ten N-P-K doses were the treatment as follows-

Number of Treatment: 10

No. of Plots: 30

N0P0K0 = No nutrient added

N0P100K100 = No N, P 12 kg ha^{-1}, K 40 kg ha^{-1}

N100P100K100 = N 70 kg ha^{-1}, P 12 kg ha^{-1} and K 40 kg ha^{-1}.

(Recommended for BRRI dhan48, BRRI rice fact sheet)

N100P25K100 = N 70 kg ha^{-1}, P 3 kg ha^{-1} and K 40 kg ha^{-1}.

N100P100K25 = N 70 kg ha^{-1}, P 12 kg ha^{-1} and K 10 kg ha^{-1}.

N100P100K75 = N 70 kg ha^{-1}, P 12 kg ha^{-1} and K 30 kg ha^{-1}.

N100P50K100 = N 70 kg ha^{-1}, P 6 kg ha^{-1} and K 40 kg ha^{-1}.

N100P0K0 = N 70 kg ha^{-1}, no P and no K.

N100P100K50 = N 70 kg ha^{-1}, P 12 kg ha^{-1} and K 20 kg ha^{-1}.

N100P75K100 = N 70 kg ha^{-1}, P 9 kg ha^{-1} and K 40 kg ha^{-1}

No. of Replication: 3

3.3 Field Operation

3.3.1 Field preparation

A power tiller was used twice to accomplish minimum tillage. After tillage, all of the stubbles were manually removed from the field. According to the design, the field was divided into unit plot size.

3.3.2 Fertilizer application

Urea, TSP, MoP and Gypsum were used as the source of N, P, K and S and zinc. All the fertilizers except urea were applied on the day of final land preparation. Urea was applied as top dressed in three equal splits at 10, 30 and 45 days after broadcasting (DAS).

Other fertilizers were applied according the recommendation of the BRRI (2008) for the **Aus** rice of the AEZ 13.

They were (kg ha-1): TSP-10.5 kg, MoP-36 kg, ZnSO4 -1.2 kg and Gypsum-7 kg.

3.3.3 Broadcasting of seedling

The pre-germinating seed were broadcasted @ rate of 22.5-30 kg ha^{-1} just after first summer rainfall in line. The Broadcasting was done on 15.05.22.

3.3.4 Care after broadcasted seedling

After establishment of seedlings, several intercultural operations such as weeding, urea split application, irrigation, and so on were carried out. Plant protection measures were also taken.

3.3.5 Weeding

Weeding was done twice during BRRI dhan48 cultivation. First weeding was done after 20 DAS and second weeding was done at 35 DAS.

3.3.6 Plant protection

Green leaf hopper (GLH) and nematode were the main pest for rice plants and to control them Nitro 505 EC (Chloropiriphos+ Cypremethrin) @1ml/L at 37 DAS and Furadan 5g @15 kg ha^{-1} at 25 DAS were applied.

3.3.7 Harvesting and postharvest operations

When 80-90 % of the grains had turned golden-yellow color then the crops were harvested. The harvesting was done on 06.08.22. Threshing was done manually after the harvest. The grains were cleaned and dried to 13% moisture content and the straw were oven dried. The grain and straw yields of each treatment were calculated and converted to t ha^{-1}.

3.4 Data collection, recording and calculation

Five hills were selected per plot to record the yield attributes of crops. The data on growth parameters (plant height and tiller number hill^{-1}) was collected from the randomly selected five plants from each plot at 60, 75 days after sowing (DAS) and at harvest. Other data were collected on effective tiller hill^{-1}, panicle length, grain panicle^{-1}, filled grain panicle^{-1}, grain yield, straw yield, biological yield and harvest index.

3.4.1 Plant height (cm)

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

3.4.2 Number of tillers hill^{-1}

The number of tillers from 4.5 m^2 was recorded at the time of 60, 75, DAT and at harvest.

3.4.3 Effective tiller hill^{-1}

Grain bearing panicle was called effective tiller. After harvesting, total number of effective tiller was counted.

3.4.4 Panicle length (cm)

From five randomly selected panicles, panicle length was measured separately from each plot.

3.4.5 Number of grain panicle^{-1}

On the basis of grain yield spikelet, the total number of grains was collected from randomly selected 5 plants in a plot, and the average number of grain panicle^{-1}was recorded.

3.4.6 Filled grain panicle^{-1}

The total number of filled grains was collected from randomly selected 5 plants in a plot, and the average number of filled grain panicle^{-1} was recorded.

3.4.7 Unfilled grain panicle^{-1}

On the basis of grain yield spikelet, the total number of unfilled grains was collected from randomly selected 5 plants in a plot, and the average number of unfilled grain panicle^{-1} was recorded.

3.4.8 Weight of 1000 grain (g)

A thousand grains were counted randomly from each individual treatment's total clean grain, then weighed in grams and recorded.

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

The grains from each treatment plot were sun dried and carefully weighed. The weight of grain harvested from a $10m^2$ area was converted to t ha^{-1}.

3.4.10 Straw yield (t ha^{-1})

Straw yield was obtained from the same way of grain yield, then sun dried, weighed carefully and converted to t ha^{-1}.

3.4.11 Harvest index (%)

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage. Harvest index are calculated by the following formula:

Harvest index (%) = Grain yield / Biological yield × 100

3.5 Statistical analysis:

The collected, calculated and recorded data on different parameters were compiled and statistically analyzed following the analysis of variance techniques (one-way ANOVA) by using 'Statistix 10'. The significant differences among the treatment means were compared following all pair wise comparison by least significant different (LSD) at 5% level of significance and the mean differences were adjusted with Duncan's New Multiple Ranges Test (DMRT).

CHAPTER-IV

RESULT AND DISCUSSION

The goal of the experiment was to investigate how NPK affects the growth and yield of the B. *Aus* rice relying on rainfed condition. The result of the experiment was presented by evaluating growth, yield attributes and yield of B. *Aus* rice in response to NPK ratio. The following headings and subheadings have been used to present and explain the results of this experiment.

4.1 Temperature, Rainfall and Salinity Status

4.1.1 Temperature of the study area

We collected temperature data from May to September from Khulna weather station. where we found minimum temperature at 21°c in 4 may, 2022 and maximum at 37.5°c in May 24, 2022. We know the optimum temperature for photosynthesis is 22-35°c. This temperature is suitable for *Aus* rice cultivation.

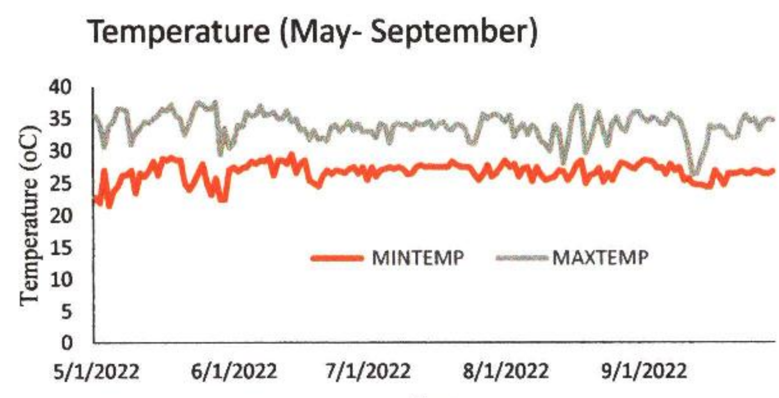

Fig. 4. Maximum and minimum temperature in the study area during the growing season

4.1.2 Rainfall of the study area

We collected rainfall data from May to September from Khulna weather station where we found 25 mm rainfall at May 10,2022. We want to carry on our experiment as a rainfed crop but the rainfall was not sufficient for cultivation, so few irrigations was done at early stage of cultivation. The maximum rainfall was recorded 150 mm at September 17, 2022 but at that time crop was harvested.

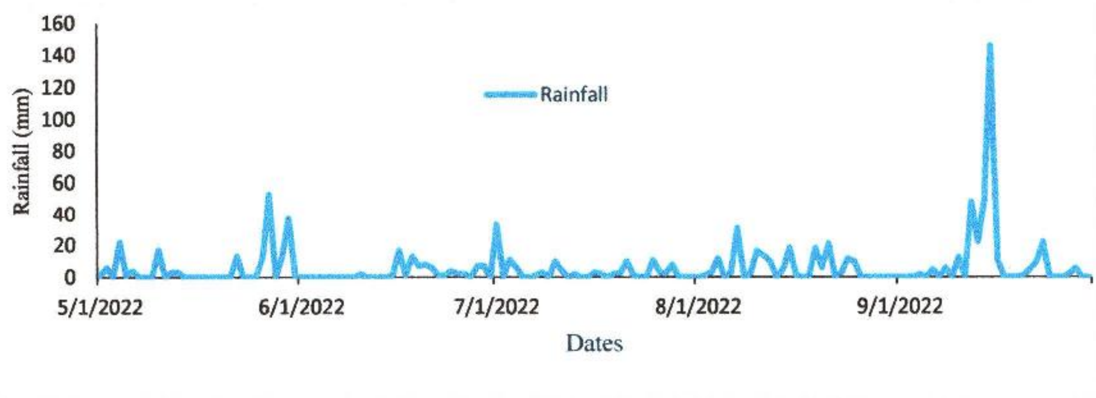

Fig. 5. Rainfall pattern during the growing period (May-August) in the experimental area from the weather station, Khulna.

4.2 Effect of NPK combination on growth parameters

4.2.1 Plant height (cm)

Plant height was statistically significant ($p<0.01$) with the application of NPK fertilizers combination at, 60, 75, DAS and at harvest (Table 1). The highest plant height was recorded from NPK combination @ 100-100-100 kg ha-1 and lowest was recorded from control treatment (no NPK added plot) at harvest. At 60 DAS, the NPK combination @ 100-100-100 kg ha-1 resulted the highest plant height which was statistically similar with the application of NPK @ 100-75-100, 100-100-25, 100-100-50 and 100-100-75 kg ha-1 and the lowest was recorded from control treatment (no NPK added plot). At 75 DAS, NPK combination @ 100-100-100 kg ha-1provided the maximum plant height which was statistically similar with the NPK applications of 100-75-100 kg ha-1 in addition, the lowest was recorded from control treatment (no NPK added plot). Nitrogen is a part of chlorophyll molecule which increases photosynthesis and helps in energy transfer (Sharma et al., 2013). Plants show vigorous growth at early stage and attain maturity more quickly that receive an adequate amount of P (Teng et al., 2013). High NPK doses boosted plant height by extending the growth period (Robinson et al., 1979).

Table 1. Effect of NPK combination on plant height (cm) of Broadcasted *Aus* rice (BRRI dhan48) in the southwestern coastal soil of Bangladesh

NPK ratio (kg ha^{-1})	Plant height (cm)		
	60DAS	75 DAS	At harvest
$N_{100}P_{25}K_{100}$	50.87±1.75bc	77.20±1.35b	91.74±3.02ab
$N_{0}P_{100}K_{100}$	41.57±1.08e	65.39±3.11c	83.89±0.81c
$N_{100}P_{100}K_{100}$	57.41±1.16a	83.37±2.55a	95.4±1.99a
$N_{0}P_{0}K_{0}$	35.57±2.11f	54.99±2.14d	82.86±0.88c
$N_{100}P_{100}K_{25}$	56.10±0.99ab	76.80±0.94b	93.23±0.90a
$N_{100}P_{100}K_{75}$	52.17±1.66abc	69.58±2.48c	91.62±0.93ab
$N_{100}P_{50}K_{100}$	50.27±2.42cd	75.98±2.48b	92.33±0.77ab
$N_{100}P_{0}K_{0}$	44.99±0.95de	64.33±0.81c	86.65±4.30bc
$N_{100}P_{100}K_{50}$	53.41±3.21abc	76.07±2.35b	94.69±0.68a
$N_{100}P_{75}K_{100}$	54.00±1.14abc	78.53±1.54ab	94.82±1.14a
LS	**	**	**
CV (%)	6.55	4.88	3.86

LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation

Values in a column having similar letters indicate the treatment means are statistically similar while dissimilar letters signifies are statistically dissimilar.

4.2.2 SPAD Value (Leaf greenness)

SPAD value was varied statistically with different application of NPK fertilizers combination. The highest SPAD value was observed at @ 100-100-100 NPK combination and the lowest was from control plot (no NPK added) (Fig. 6). At 60 DAS the highest SPAD value was obtained from @ 100-100-100 NPK combination. The lowest SPAD value was observed from control plot (no NPK added which was statistically similar with @ 0-100-100 NPK combination. At 75 DAS the highest SPAD value was obtained from @ 100-100-100 NPK combination and the lowest was from control plot (no NPK added which was statistically similar with @ 0-100-100 NPK combination.

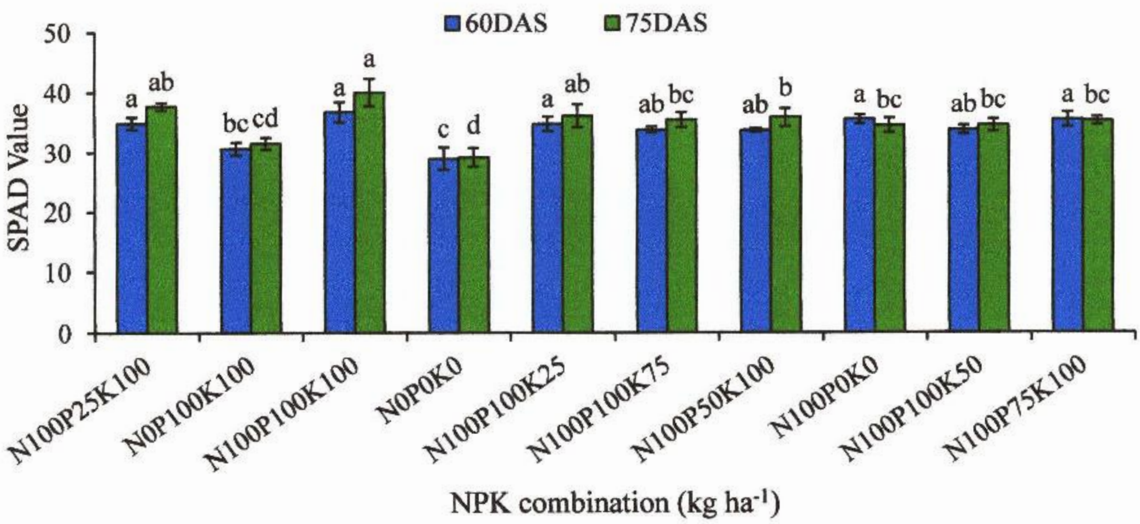

Figure 6. Effect of various NPK combination on SPAD value of BRRI dhan48 rice in southwestern coastal Bangladesh. The similar letter on the bar indicates the mean are statistically similar while the dissimilar letter on the bar are statistically non-significant The small bar on each bar signifies standard error (±SE).

4.2.3 Tiller number per square meter

Tiller number was statistically significant (*$p<0.01$*) at, 60 and 75 DAS (Table 2). At 60 and 75 DAS, the highest tiller number was recorded from NPK combination @ 100-100-100 kg ha^{-1} and the lowest was recorded from control treatment (no NPK added plot). Maximum tiller number was resulted from NPK combination @ 100-100-100 kg ha^{-1} which was statistically similar with the application of NPK @ 100-75-100 kg ha^{-1} at 60 DAS. At 75 DAS, statistically highest tiller number was obtained from NPK combination @ 100-100-100 while lowest was recorded from control treatment (no NPK added plot) followed by @ 0-100-100 combination. Nitrogen increases number of tillers per hill. Azam et al. (2012), Das, (2011) and Yaqub et al. (2010) reported comparable findings from their study. According to Warraich et al. (2002) P fertilization causes plant to produce more higher viable tillers/m^2 and biological yield. According to Singh and Singh, (2002) increasing nitrogen levels resulted in a large increase in total tillers $hill^{-1}$ up to a certain stage. Haque et al. (2023) showed in the same variety that N application produced highest number of tiller.

Table 2. Effect of NPK combination on tiller number per square meter of Broadcasted *Aus* rice (BRRI dhan48) in the southwestern coastal soil of Bangladesh

NPK ratio (kg ha^{-1})	Tiller number per square meter	
	60DAT	75 DAT
$N_{100}P_{25}K_{100}$	187.67±8.09bc	167.00±8.39bc
$N_{0}P_{100}K_{100}$	152.00±3.51d	129.67±3.18e
$N_{100}P_{100}K_{100}$	212.00±20.55a	218.33±3.76a
$N_{0}P_{0}K_{0}$	149.33±9.77d	125.00±1.53e
$N_{100}P_{100}K_{25}$	181.33±7.97bc	152.00±13.43cd
$N_{100}P_{100}K_{75}$	184.00±4.16bc	150.67±1.76cd
$N_{100}P_{50}K_{100}$	178.67±7.51bc	166.00±11.36bc
$N_{100}P_{0}K_{0}$	169.67±0.88cd	143.67±1.20de
$N_{100}P_{100}K_{50}$	182.33±2.03bc	144.67±3.93de
$N_{100}P_{75}K_{100}$	202.00±2.65ab	174.00±1.15b
LS	**	**
CV (%)	7.59	7.47

LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation

Values in a column having similar letters indicate the treatment means are statistically similar while dissimilar letters signifies are statistically dissimilar.

4.3 Effect of NPK combination on yield attributes

4.3.1 Panicle length (cm)

Panicle length was differed statistically (*$p<0.01$*) with the application of NPK fertilizers combination (Table 3). NPK combination @ 100-100-100 kg ha^{-1} produced the maximum panicle length and the minimum was found from no NPK added plot followed by combination of 0-100-100. Panicle length increased with higher level of NPK application and decreased in control treatment. Maximum panicle length was obtained at highest level of nitrogen application (Yoseftabar, 2013 and Metwally et al., 2017). Maximum panicle length was reported at highest level of nitrogen application (Ghoneim and Osman, 2018). The addition of K to the soil may aid in the utilization of soil pH and increase the amount of macro- and micronutrients in the soil, resulting in increased plant development during the reproductive stage and the production of the longest panicle (Islam et al., 2015).

4.3.2 Number of effective tiller $hill^{-1}$

Number of effective tillers $1m^2$ was differed statistically (*$p<0.01$*) with the application of NPK fertilizers combination (Table 3). NPK fertilizer @ 100-75-100 kg ha^{-1} resulted the maximum number of effective tiller and no NPK added plot was resulted the minimum followed by 0-100-100 combination. NPK combination @ 100-7-100 kg ha^{-1} was recorded statistically comparable to the maximum one ((@ 100-100-100 kg ha^{-1}. Hari et al. (2000) have found similar observation that with increasing levels of nitrogen the number of effective tillers also increases. Add support from Haque et al. (2023) and Sumona Thesis on this variety.

4.3.3 Number of filled grain $panicle^{-1}$

With the application of different NPK fertilizer combinations, the number of filled grain per panicle was statistically different (p<*0.01*) (Table 3). NPK combination @ 100-100-100 kg ha^{-1}

provided the highest number of filled grain per panicle which was statistically at par with the application of NPK fertilizer @ 100-75-100, and 100-50-100 kg ha^{-1} and the lowest was observed from no NPK added plot followed by 0-100-100 combination. With the increasing application of N-P-K fertilizer, number of filled grain $panicle^{-1}$ also increased. Increases in grain yield as a result of NPK fertilizer foliar application increases in yield components, such as number of panicles per square meter, full grains percentage, and quantity of grain per panicle (Manik et al., 2016 and Shrestha et al., 2020).

4.3.4 Number of unfilled grain $panicle^{-1}$

With the application of different NPK fertilizer combinations, the number of unfilled grains per panicle was statistically different ($p<0.01$) (Table 3). The highest number of unfilled grains per panicle was observed from @100-0-0 which is statistically similar to 100-50-100 and the lowest was observed from @ 100-100-50 kg ha^{-1} moreover, the number of unfilled grains per panicle statistically similar with rest of the treatments except @ 100-100-100 combination. A considerable increase in the number of unfilled grains per panicle was seen with higher nitrogen application rates for all rice genotypes. This increase in unfilled grains could be linked to the formation of more spikelet per plant as well as photo-assimilation. Metwally and Abdelkhalik, (2010) and Ghoneim, (2014) have found similar results.

Table 3. Effect of NPK combination on yield contributing character of Broadcasted *Aus* rice (BRRI dhan48) in the southwestern coastal Bangladesh

N-P-K ratio (kg ha^{-1})	Panicle length (cm)	Effective tiller (1 m^2)	Filled grain $panicle^{-1}$	Unfilled grain $panicle^{-1}$
$N_{100}P_{25}K_{100}$	18.51±0.98bc	645.33±16.22cd	78.00±1.53de	32.33±1.33bc
$N_0P_{100}K_{100}$	13.97±0.61d	544.00±8.33f	67.33±0.33g	27.67±3.53bc
$N_{100}P_{100}K_{100}$	23.11±0.89a	758.67±5.81a	108.00±4.04a	33.00±1.73b
$N_0P_0K_0$	12.00±0.78d	537.33±7.42f	57.00±1.15h	27.33±0.33bc
$N_{100}P_{100}K_{25}$	20.38±0.29b	610.67±3.53de	72.00±1.53fg	28.00±2.00bc
$N_{100}P_{100}K_{75}$	18.36±0.45bc	673.33±42.73bc	90.33±3.48c	31.33±0.33bc
$N_{100}P_{50}K_{100}$	18.85±0.68b	720.00±20.53ab	104.00±2.31a	42.00±1.00a
$N_{100}P_0K_0$	19.71±1.22c	596.00±8.33e	73.67±0.33ef	42.33±5.67a
$N_{100}P_{100}K_{50}$	17.92±0.84bc	696.00±4.62b	83.67±1.86d	24.67±0.88c
$N_{100}P_{75}K_{100}$	18.98±0.75b	750.67±11.62a	97.67±0.33b	30.00±3.61bc
LS	**	**	**	**
CV (%)	7.84	4.25	4.09	14.60

LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation

Values in a column having similar letters indicate the treatment means are statistically similar while dissimilar letters signifies are statistically dissimilar.

4.4 Yield Attributes

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

With the application of different NPK fertilizer combinations, grain yield was statistically different ($p<0.01$). NPK combination @ 100-100-100 kg ha^{-1} significantly produced the highest grain yield. Whereas the lowest was recorded from control plot (no NPK added) which is statistically similar to @ 0-100-100. NPK combination @ 100-100-100 kg ha^{-1}improved the grain yield than other combination. Enhanced NPK fertilizer rates may have increased grain yields, possibly due to adequate nutrition availability to the crops, resulting in higher panicle numbers and a higher percentage of productive tillers. NPK fertilizer treatment can improve plant height, number of panicle hill^{-1}, number of productive panicle hill^{-1}, and dry grain yield, according to Samira et al.,(2012).

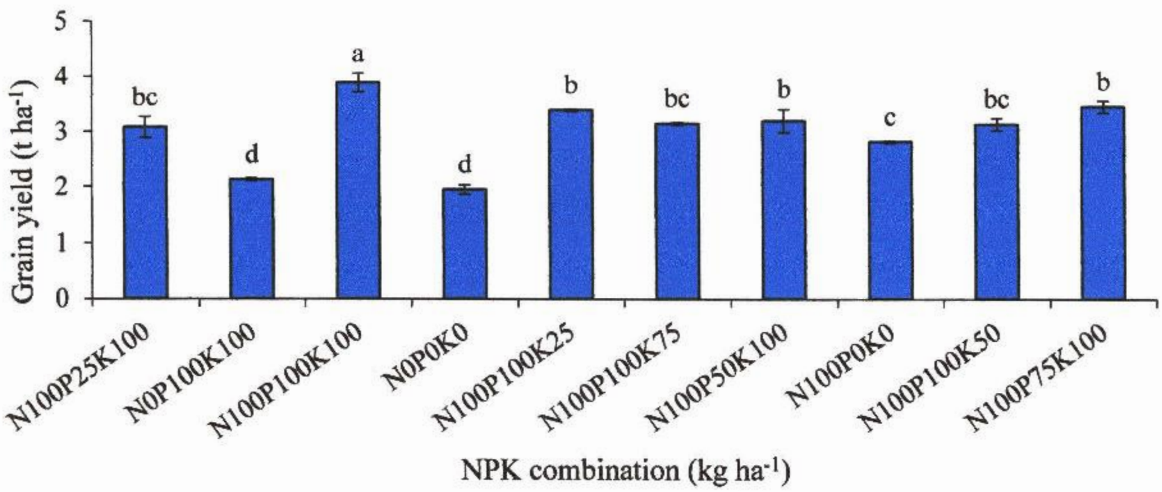

Figure 7. Effect of various NPK combinations on grain yield of BRRI dhan48 rice in southwestern coastal Bangladesh. The similar letter on the bar indicates the mean are statistically similar while the dissimilar letter on the bar are statistically non-significant The small bar on each bar signifies standard error (±SE).

4.4.2 Straw yield (t ha^{-1})

Straw yield (t ha^{-1}) was varied statistically with different application of NPK fertilizers combination. The highest straw yield was found when the combination of NPK fertilizer application was @ 100-100-100 kg ha^{-1} and the lowest was found with control treatment (no NPK added plot). A greater nitrogen level may have aided the straw yield. Rahman et al. (2016) reported that fertilizer management differences in grain production and straw yield. The straw yield at different levels of nitrogen application ranged from 2.37 t ha-1 to 4.52 t ha-1 (Table 3).

Sumona,2022 stated the maximum straw yield (4.52 ton ha-1) was obtained from application of 104 kg N ha-1 which was statistically similar with all treatments except N0. The lowest straw yield (2.55t ha-1) was obtained from N0.

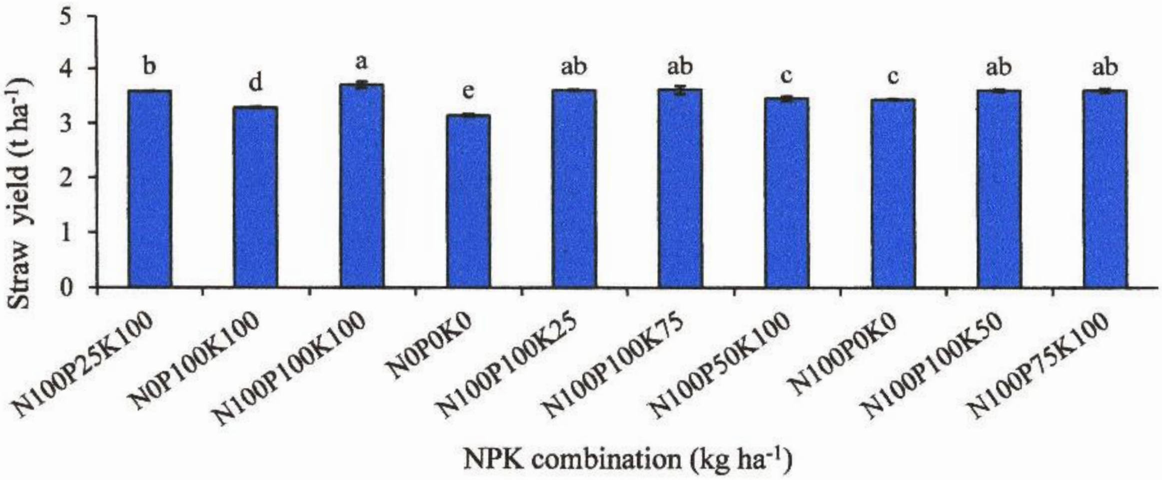

Figure 8. Effect of various NPK combination on straw yield of BRRI dhan48 rice in southwestern coastal Bangladesh. The similar letter on the bar indicates the mean are statistically similar while the dissimilar letter on the bar are statistically non-significant The small bar on each bar signifies standard error (±SE).

4.4.3 1000 grain weight (g)

Numerically the maximum weight was found at @ 100-100-100 kg ha^{-1} which was statistically comparable to rest of the treatments and the minimum was found from @100-100-25. Nitrogen fertilizer raised the weight of 1000 grains significantly by producing greater number of spikelets per $panicle^{-1}$. As a result of the high sink capacity compared to the limited corresponding source, the grain filling was greater and, as a result, the grain weight was greater. Metwally et al. (2010), Ghanbari-Malidareh, (2011) and Sorour et al. (2016) all reported on the effects of nitrogen on 1000-grain weight. Elevated phosphorus levels, especially when deposited in the leaves prior to the flowering stage, have the potential to contribute to an increase in the weight of 1000 grains during the flowering stage, as suggested by Yoshida in 1981.

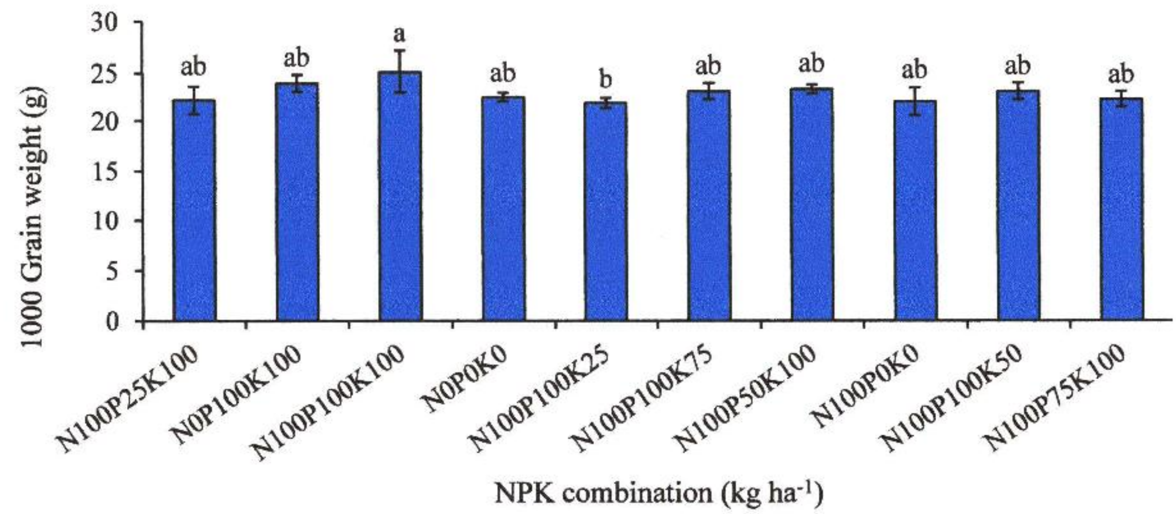

Figure 9. Effect of various NPK combination on 1000 Grain weight of BRRI dhan48 rice in southwestern coastal Bangladesh. The similar letter on the bar indicates the mean are statistically similar while the dissimilar letter on the bar are statistically non-significant The small bar on each bar signifies standard error (±SE).

4.4.4 Harvest index (%)

Effect of different N-P-K fertilizers combination on harvest index was differed statistically (*p<0.01*). NPK combination @ 100-100-100 kg ha^{-1} was resulted the highest harvest index and the lowest was recorded from control plot (no NPK added) which was statistically similar with @ 0-100-100 NPK combination.

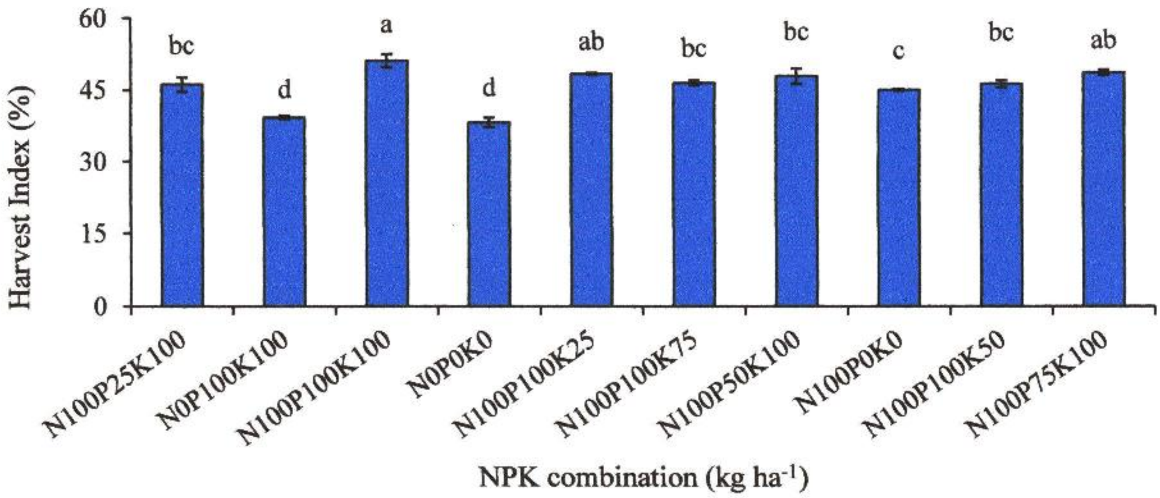

Figure 10. Effect of various NPK combination on harvest index of BRRI dhan48 rice in southwestern coastal Bangladesh. The similar letter on the bar indicates the mean are statistically similar while the dissimilar letter on the bar are statistically non-significant The small bar on each bar signifies standard error (±SE).

CHAPTER-V

SUMMARY, CONCLUSION AND RECOMMENDATION

The experiment was carried out from May to August, 2022 for determining the optimum NPK rate for achieving the highest grain yield and yield component in HYV Broadcasted *Aus* rice BRRI dhan48. There were 10 different level of NPK combination as @ (kg ha^{-1}) 0-0-0, 0-100-100, 100-0-0, 100-25-100,100-100-100, 100-100-25, 100-100-75, 100-50-100, 100-100-50 and 100-75-100 per cent of recommended N, P, K. with three replications.

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The NPK combination of @100-100-100 kg ha^{-1} significantly produced ($p< 0.01$) the highest plant height, tiller number, panicle length, number of filled grain $panicle^{-1}$,1000 grain weight, grain yield, straw yield, biological yield, SPAD value, effective tiller except unfilled grains (@ (100-0-0 kg ha^{-1}) and lowest was produced from no NPK added plot. The NPK combination of @100-10-100 kg ha^{-1} provided the highest harvest index, which was statistically similar to @100-100-50 and 100-75-100 kg ha^{-1}, whereas the control plot produced the lowest (no NPK added). In comparison to other application ratios, the NPK combination @100-100-100 kg ha^{-1} increased grain yield by 9.23-83.58%. This result of this experiment revealed that N is the main driving element that greatly influence the growth, yield attributes and yield of rice while P and K had minor influence. The soils in this region contains enough P and K that might fulfill the demand of rice. But there was shortage of nitrogen in the experimental soil. The finding of the study suggested that phosphorus and potassium fertilizer requirement should be much below than the current recommendation and nitrogen requirement was found optimum. So, reduction of nitrogenous fertilizer decreases the yield (~42%) but the reduction of phosphorus and potassium fertilizer did not decrease the yield as same rate as N. From the findings of this study, we concluded that NPK (kg ha^{-1}) @ 100-100-100 percent of recommended N, P, K is suitable combination for the cultivation of BRRI dhan-48 in the coastal soils of southwestern Bangladesh.

In short *Aus* rice cultivation is possible in Kharif-1 season by broadcasting the seed just after starting of summer rainfall in the SW coastal region of Bangladesh. This experiment was conducted in one year and in single location. Further study should be done with NPK combination on B. *Aus* in other areas of the southwestern region and more similar research is needed in this agro ecological zone (AEZ-13) of Bangladesh.

CHAPTER-VI

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