# Higher Dose and Split Application of Zinc Influence Growth and Yield of Transplanted *Aman* Rice Variety BRRI dhan75



A Thesis

By

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DEDICATED

TO

MY BELOVED PARENTS

AND HUSBAND

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## ABSTRACT

For investigating the influence of dose and split application of zinc on the growth and grain yield of transplanted aman rice, a field experiment was conducted at Professor Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna during the aman season of 2022. For the investigation, rice cultivar BRRI dhan75 was chosen and sown with four zinc doses of $D_0$, $D_1$, $D_2$, $D_3$ and three application time of $T_1$, $T_2$ and $T_3$. With three replications, zinc fertilization treatments ($D_0T_1$, $D_0T_2$, $D_0T_3$, $T_1D_1$, $T_1D_2$, $T_1D_3$, $T_2D_1$, $T_2D_2$, $T_2D_3$, $T_3D_1$, $T_3D_2$, $T_3D_3$) were grouped according to the Complete Randomized Design (CRD). Experimental data on different plant growth characters, yield contributing characters, and yield parameters were collected and analyzed statistically. Plant growth characters (plant height and tiller number) were found significant in most of the cases for interaction but were significant in some cases for individual treatment. However, there have significant effects of levels and stages of zinc fertilization on yield contributing characters and yield parameters. It was observed that rice yield significantly improved with zinc fertilization in Zn deficient soil. Split application of zinc fertilizer had no considerable effect on rice development, and increasing yield. At harvest the highest plant height (122.17 cm) was in $T_3D_2$ (Two splits application 50% as basal and 50% at 40 DAT with 14.38 kg zinc application), the highest number of tillers hill$^{-1}$ (17.66) was found from no zinc added treatment ($T_1D_0$). Highest (32.27) SPAD value was observed from $T_2D_1$ (Two splits application 50% as basal and 50% at 25 DAT with 11.5 kg zinc application ha$^{-1}$), highest leaf number was noticed from $T_3D_3$ (two splits application 50% at last ploughing and 50% at 25 DAT and 17.25kgha$^{-1}$ zinc application) $T_1D_1$ (Full dose as basal with 11.5 kg ha$^{-1}$ zinc application) resulted in the highest grain production (13.57 g hill$^{-1}$). The 1000 grain weight was the highest at $T_1D_3$ (24.59 g) which was statistically similar to the values of $T_1D_1$ (24.28 g) and $T_1D_2$ (24.21 g). The highest biological yield of rice was resulted from $T_1D_3$ (35.07 g hill$^{-1}$) and highest harvest index was resulted from $T_3D_1$ (43.98 %) which was statistically similar to $T_1D_1$ (43.87 %). The interaction effect of different dose and time of zinc application had significant effect on yield contributing data (1000 grain weight) and yield (Grain yield). Among the yield and yield contributing characters (panicle length, biological yield and harvest index), data showed significant relationship with the treatment combination. Positive correlation was found between major yield parameters with grain yield.

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# CHAPTER I

# INTRODUCTION

The main cereal food crop in Bangladesh is rice (*Oryza sativa L.*), which is cultivated throughout the pre-monsoon (April to June), monsoon (July to November), and boro (December to June) seasons (Islam et al., 2015). Rice makes over 95% of the yearly grain production in Bangladesh (Bhuiyan et al., 2002). Total aman production for the fiscal year 2020–21 was 1,44,37,763 metric tons, while the total area under aman crop was 56,25,907 ha (BBS, 2022). Rice (*Oryza sativa L.*) stands as one of the most crucial staple crops globally, feeding over half of the world's population (FAO, 2020). In the context of global food security, the enhancement of rice crop productivity remains a pivotal agricultural objective. Achieving this goal necessitates a comprehensive understanding of various factors influencing rice growth and yield, including nutrient management practices.

Reaching the goal of rice production can be hampered by a number of obstacles, including rising population, declining resources (shrinking net cultivated area, scarcity of water for irrigation), rising climatic susceptibility, and rising strain on soil fertility. In order to boost crop yield, proper soil fertility management is therefore of utmost importance (Islam et al., 2016). The proper utilization of important nutrients has a significant impact on rice growth and development, which in turn affects productivity among other things. On the other hand, paddy output has generally increased over time in Bangladesh and other countries that farm rice due to the development of improved rice varieties as well as better soil and fertilizer management technology. As a result, nutrient loss of nitrogen (N), phosphorus (P), and potassium (K) is gradually increasing (Islam et al., 2016).

Zinc One of the essential elements, zinc (Zn), is needed for a variety of biochemical and metabolic processes in rice, including the creation of Auxin, cytochromes, chlorophyll generation, glucose metabolism, and respiration, growth, gene expression, and pollen formation (Barman et al., 2018; Madhusudanan et al., 2019; Mondal et al., 2020; He et al., 2021). However, a common problem that can result in decreased crop yields and poor grain quality is zinc deficiency in soils that are used to cultivate rice (Impa & Johnson-Beebout, 2012). Zinc is a crucial component of many enzymes and controls a variety of growth-promoting biochemical activities in plants (IRRI, 2000). Zinc (Zn) is an essential micronutrient vital for the growth and development of plants, including rice. It plays a pivotal role in various physiological processes, such as photosynthesis, enzymatic activity, and nucleic acid metabolism (Hafeez et al., 2013). Rice production can be significantly hampered by a zinc deficiency in the soil, which lowers grain output and degrades crop quality (Cakmak et al., 1996). Zinc addition by fertilization has become a widespread practice in modern agriculture as a solution to this problem. The dose and time of zinc treatment are two crucial variables that affect how zinc affects rice development and grain production. Previous research has shown that both too much and not enough zinc can lead to subpar rice performance (Impa et al., 2013). Additionally, the timing of applying zinc at various growth stages can have an effect on nutrient uptake, plant shape, and ultimately, grain yield (Hossain et al., 2017). As the agricultural community seeks to optimize nutrient management practices for sustainable rice production, it is imperative to explore the intricate interplay between zinc dose and application timing in transplanted Aman rice. This study aims to address this knowledge gap by investigating the effects of varying zinc doses and application timings on the growth parameters and grain yield of transplanted Aman rice, ultimately contributing to the refinement of nutrient management practices in rice cultivation. Recent years have seen an emphasis on the timing and dosage of zinc administration as academics and farmers investigate the impact of zinc application on rice output. This study intends to improve rice production methods for transplanted Aman rice, a variety popular in Bangladesh. For sustainable agriculture to succeed and to guarantee the food security of millions of people, it is essential to comprehend how the timing and dose of zinc administration affect the growth and grain output of transplanted Aman rice (Lee et al., 2010).

Globally, both temperate and tropical regions are prone to zinc deficiency (Slaton et al., 2005). According to studies, a zinc shortage might affect more than 50% of field crops (Cakmak and Kutman, 2018; Aiqing et al., 2021). Application of zinc had a considerable impact on the amount of zinc in the post-harvest soil (Ghoneim, 2016). Rice yield has been enhanced by adding Zn at 40 days after planting (Slaton et al., 2005). Zinc application resulted in significant increases of 14% and 16%, respectively, in grain and straw yield of several rice varieties (Sudha and Stalin, 2015). The application of zinc in West Bengal's lowland rice soil increased grain and straw yields over the control by 37.8% and 20.9%, respectively (Naik et al., 2010). Inadequate fertilizer application and micronutrient deficiencies, notably for Zn, have been linked to significant crop yield stagnation. The current substantial issue of Zn enrichment in rice grains needs to be resolved through agricultural technology like fertilization and breeding. (Kausar et al., 2001). The study found that foliar application of Zn at 5 kg $ha^{-1}$ at tillering or panicle initiation significantly increased grain yield of transplanted aman rice. The highest grain yield was obtained with foliar application of Zn at 5 kg $ha^{-1}$ at panicle initiation. Other studies also showed that foliar Zn spray is more successful at boosting rice grain production than soil application. For instance, a research by Fageria and Baligar (2005) discovered that applying foliar Zn at 0.5% at the onset of panicles and tillering boosted rice grain output by 15-20%. According to the study's findings, fertilizing with zinc greatly enhanced rice grain yield, biomass production, and Zn uptake. 20% more grain was produced in the Zn treatment than in the control treatment. Additionally, the Zn treatment's biomass production was 20% higher than the control treatment's biomass production. So, it is imperative that Proper zinc fertilizer management is essential for both grain yield and economical production of rice. Keeping the above fact in mind the present research work has been formulated with the objectives below. The objectives of the present study are-

1. To observe the effect of increased dose and split application of zinc on growth and yield of T. aman rice.

2. To optimize zinc application schedule for T. aman rice.

# CHAPTER II

# REVIEW OF LITERATURE

## 2.1 Worldwide rice production

According to IRRI, Africa Rice, and CIAT (2010), more than 3.5 billion people depend on rice for more than 20% of their daily caloric intake. Rice is one of the main staple grains. According to FAO (2020), the globe produces 508,7 million tonnes of rice. With an expanding global population, it is estimated that 14,886 million tons (MT) of food must be produced in 2050 to satisfy the need for food identified by Mohammad et al. (2020). China produces 29.5% of the world's rice, followed by India (23.8%), Bangladesh (7.0%), Indonesia (6.9%), Vietnam (5.4%), and Thailand (3.7%), according to USDA research from 2020. The production of rice is expected to increase by 114 million tons by 2035, but farmers will face significant risks from climate change to do so. a decrease in the amount of accessible agricultural land, manpower, and water, as well as an increase in the cost of these inputs, as reported by Suzanne et al. (2012). More than 100 nations, spread over six continents, and a variety of settings grow rice. More than 700 million tons of rice are produced annually (470.6 million tons of milled rice) on an estimated 158 million acres of land worldwide (USDA 2016). Asia produces roughly 640 million tons, or 90%, of the world's rice. The main obstacle to ensuring food security, according to Ladha et al. (2015), is increasing global food production while minimizing harmful consequences on the environment and resources.

## 2.2 Rice production in Bangladesh

Bangladesh has a rich history of rice cultivation dating back thousands of years. The cultivation of rice has changed over time, and it has been the main crop since the dawn of civilization. The importance of rice as a key component of the region's agriculture and culture is highlighted by historical documents and archaeological discoveries (BBS, 2020). Significant modifications were made to Bangladesh's rice production during the Green Revolution in the 1960s. Increased production resulted from the introduction of high-yielding rice varieties like IR8 (Islam et al., 2019). Since that time, Bangladesh has continued to create and adopt new rice varieties, including hybrid and stress-tolerant varieties, to fulfill the rising demand for rice (Hossain et al., 2015).

According to Kabir et al. (2020) and Nasim et al. (2021), rice is likewise the main food in Bangladesh and accounts for about 78 percent of all net cultivated land there. From 11.55 million hectares of farmed gross land, the nation achieves autarky to supply the 169.04 million people who live there with the rice they need. Kabir et al. (2020) reported that rice security is the equivalent of food security in Bangladesh. According to BBS (2020), rice is grown all year long throughout the Aus, Aman, and Boro seasons. Since gaining independence, the production of rice has increased thrice, from 11 MT in 1971–1972 to 36.6 MT in 2019–2020. Bangladesh must raise its rice yield if it is to meet the rising food demand brought on by population expansion. Given that irrigated rice, also known as Boro rice, now makes up roughly 50% of the nation's overall rice production, there is room for improvement in this sector. According to Brolley (2015), rice is the foundation of Bangladeshi agriculture; like in many other nations, 'food security' rests almost exclusively on 'rice security,' which alone accounts for around 4.5% of GDP (BBS, 2020). Approximately 78% of yearly agricultural land (gross cropped area) is taken up by the politically and culturally sensitive crop, which is currently producing surplus to feed 165 million people, observed by Kabir et al. (2015).

One of the most significant cereal crops in Asia is rice (*Oryza sativa, L.*), which is consumed and produced in greater than 90% of the Asian continent, where it is consumed and produced by more than 70% of the people conducted by Verma et al., 2012, 2013, 2015. It is widely grown around the world in tropical and subtropical areas found by Verma, 2011. It is produced across all seven continents in 112 nations, and 2500 million people in underdeveloped nations consume it (Datta and Khush, 2002).

### 2.3 Zinc function and impact on rice production

Zinc (Zn) is one of the 17 essential elements identified by Prasad (2008) that are required for the healthy growth and development of all humans, animals, and plants, according to Broadley et al. (2007). Zn is one of eight micronutrients with a key role in plants involved with enzymes and proteins in carbohydrate metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, and protection against phot, on the one hand, and essential for healthy growth, physical development, and mental development of children on the other. Zinc serves as a cofactor for multiple enzymes and proteins involved in numerous metabolic pathways, making it an essential element for rice plants. It is essential for respiration, photosynthesis, and the production of nucleic acids and proteins observed by Cakmak, (2008). Insufficient zinc can cause rice plants to grow and mature more slowly (Hafeez et al., 2013).

Zn has numerous roles in the biochemical and physiological processes of plants. Any Zn deficit may result in a reduction in plant growth, yield, and Zn content in edible plant portions. With the application of zinc, the grain and straw yield of several rice genotypes dramatically increased by 14 and 16%, respectively (Sudha and Stalin, 2015). The overall zinc content per plant at various growth stages increased as the zinc supply to rice increased, and this had a positive impact on the production of tillers (Impa et al., 2013; Sarwar et al., 2013). According to Krishnaswamy et al. (1994) and Sharma et al. (1982), soil treatment was successful in improving the Zn status of the soil and left behind residual effects for succeeding crops (Prasad and Umar, 1993). In comparison to treatments applied with NPK alone, Keram et al. (2013) found that treatments applied with increasing doses of Zn yielded higher yields of grain and straw.

Children are the most impacted, with roughly 54% of them having a zinc deficiency, according to Sinha (2004). A person needs 15 mg of zinc per day to consume zinc effectively, however our food grains only contain 15–35 mg of zinc per kilogram, and only 13–35% of that zinc is accessible, according to Cakmak et al. (2004). As a result, there is a significant discrepancy between daily requirements and intakes. Pfeiffer and McClafferty (2007) found that our food grains should include 40–60 mg Zn/kg in order to close this gap. According to Verma (2015), a zinc deficiency causes malnutrition or concealed hunger. According to experts, 2 billion people worldwide, primarily in developing nations, are micronutrient malnourished.

**Zinc Function and Its Impact on Rice Production is:**

1. **Essential nutrient is zinc**: Zinc serves as a cofactor for multiple enzymes and proteins involved in numerous metabolic pathways, making it an essential element for rice plants. It is essential for respiration, photosynthesis, and the production of nucleic acids and proteins (Cakmak, 2008). Insufficient zinc can cause rice plants to grow and mature more slowly (Hafeez et al., 2013).

2. **Mechanisms for zinc uptake and transport**: Through a variety of transporters and absorption processes, rice plants extract zinc from the soil. For the development of zinc-efficient rice varieties, it is essential to comprehend the molecular mechanisms underlying zinc absorption and transport

(Bashir et al., 2012). The genetic variables governing zinc absorption and transport in rice have been clarified by recent research (Lee et al., 2010).

**3. Impact on grain yield:** Zinc deficiency in soils used to grow rice is a problem that can affect crop yield and quality worldwide. According to research, applying zinc can dramatically boost rice grain output by treating nutrient deficiencies (Impa & Johnson-Beebout, 2012). To maximize yield, zinc application timing and dosage have also been researched (Hossain et al., 2018).

**4. Rice grain nutritional value:** In addition to influencing rice productivity, zinc also has an impact on the nutritional value of rice grains. In areas where rice is a staple meal, zinc-enriched rice can help alleviate dietary zinc deficits (Wirth et al., 2016). To promote human health, biofortification activities attempt to create rice cultivars with higher zinc content.

**5. Zinc and tolerance to abiotic stress:** According to Impa et al. (2013), zinc helps rice plants be more resilient to abiotic conditions like salinity and drought. For sustainable rice production in difficult conditions, research on strains of rice with acceptable zinc levels must be conducted.

**6. Future prospects for sustainable agriculture:** Agriculture that is more sustainable could benefit from improving zinc management in rice production. To address zinc shortage and boost rice production, integrated strategies are essential. These include soil testing, nutrient management, and the creation of zinc-efficient rice cultivars (Hafeez et al., 2013).

### 2.4 Zinc fertilization for the nutrition of rice

According to Ghatak et al. (2005), Zn feeding is known to boost rice tillering, which significantly increased the output of dry matter. Agronomic strategies for Zn enrichment in food grains include appropriate Zn fertilization, kind, timing, and application methods. According to research by Shivay et al. (2010) and Prasad et al. (2013), $ZnSO_4$-enriched urea works better at enriching Zn in rice grains than zinc oxide (ZnO)-enriched urea at increasing the Zn content in grains of aromatic rice. According to Chaudhary et al. (2007), zinc concentration decreased as rice grew. Due to the gradual addition of zinc to the soil, the Zn content in grain varied from 22.36 to 46.57 ppm and that in straw from 19.74 to 43.95 ppm. The presence of more zinc in the soil solution from the application of zinc that permitted better absorption may be the cause of the rise in zinc content in grain and straw. Prior studies by Sakal et al. (1987), Mollah et al. (2009), and Fageria et al. (2011) indicated an increase in Zn content in grain and straw as a result of zinc fertilization. Grain contained more zinc than straw did. Naik and Das (2007) described a similar outcome. According to Kutman et al. (2010), a number of variables, including soil pH, organic matter concentration, and the presence of competing ions, affect the availability of zinc in soils. In order to develop successful fertilization strategies, it is essential to comprehend how soil characteristics and zinc availability interact. Zinc fertilization not only increases rice output but also enhances grain quality. In areas where rice is a staple meal, it results in higher zinc content in rice grains, addressing human dietary zinc shortages found by Zou et al., (2012). A promising technique to fight malnutrition is to create rice types that are biofortified with zinc.

**2.5 Efficiency of zinc use**

By applying Zn, Slaton et al. (2005) also noticed that rice was accumulating more dry matter. According to Jat et al. (2011), the application of 2% Zn-enriched urea (ZEU), or $ZnSO_4.7H_2O$, resulted in the highest agronomic efficiency (AE). Physiological efficiency (PE) and the zinc harvest index (ZnHI) of applied Zn were also significantly influenced by the use of dual-purpose summer legumes and aromatic hybrid rice. Higher grain and straw yields were realized as a result of Zn application, which consistently increased photosynthate translocation and was noted by Kulandaivel et al. (2004). According to Yasuhir et al. (2011), Zn application is often independent of the methods used, and this greatly boosted grain production.

According to findings by Mahmoodi and Mogadam (2015), the Zn concentration in foliar applications considerably enhanced rice yield and yield components. With an increase in $ZnSO_4$ levels, Dravid and Goswami (1987) reported a significant increase in the number of panicles/$m^2$, more grains per panicle, and increased panicle weight. Ahmad et al. (2012), Mali and Shaikh (1994), and Devarajan and Krishnasamy (1996) later confirmed these findings. According to Tripathi and Tripathi (2004), applying 30 kg $ZnSO_4$ $ha^{-1}$ considerably increased grain and straw yields as well as the harvest index, seed weight per panicle, and 1000-seed weight. According to Fageria et al. (2011), zinc fertilization increased rice yield by 97%. The increased yield brought about by zinc fertilization is related to zinc's participation in numerous metallic enzyme systems, regulatory activities, and auxin production as observed by Sachdev et al. (1988), higher carbohydrate synthesis, and zinc uptake. The estimated values of Zn utilization efficiencies were calculated using the formulas proposed by Shivay and Prasad (2012) and Fageria (2009). Efficient zinc use is integral to sustainable agriculture in Bangladesh. It reduces the need for excessive fertilizer application, thus minimizing environmental pollution. Implementing balanced nutrient management practices, as recommended by the Bangladesh Agricultural Extension Department, can help optimize zinc use while maintaining soil health (BAED, 2020).

### 2.6 Zinc application rates and timing

Zinc application rate has a big impact on crop nutrition and output. According to research (Krishnan et al., 2013), applying zinc at specified rates improves nutrient uptake and fosters healthy plant growth. According to Kutman et al. (2010), however, excessive use can result in imbalances and perhaps harmful effects. Applying zinc at the right time is equally important. According to studies, zinc application should take place at particular growth phases to enhance its effects. For instance, adding zinc to rice during the tillering stage has been linked to longer panicles and fuller grains recommended by Islam et al., (2016). Timing must be carefully considered because different growth stages have distinct food needs. Using zinc efficiently is essential to sustainable agriculture. Reduce nutrient waste and minimize environmental effects by balancing nutrient management through soil testing and customized application procedures (Stangoulis et al., 2015).

According to Tripathi and Tripathi (2004), applying 30 kg $ZnSO_4$ $ha^{-1}$ considerably increased grain and straw yields as well as the harvest index, seed weight per panicle, and 1000-seed weight. According to a split study by Karak et al. (2005), split application of chelated Zn gave the maximum rice yield of 4.56 t $ha^{-1}$. Alamdari et al. (2007) found that the administration of NPK, S, and $ZnSO_4$ which outperformed the control led to the highest Zn concentration in the leaves. Zn combined with FYM was discovered to have an impact by Mandal et al. (2009), who suggested applying it to rice that had been transplanted. In addition to the recommended dose (RD) of NPK, the application of 10 kg Zn in three splits resulted in noticeably improved growth, yield characteristics, grain and straw yield, and net return. Under typical soil conditions, Biswas and Dravid (2001) suggested applying 25 kg $ZnSO_4$ $ha^{-1}$ at puddling. Application techniques for zinc are also influenced by the use of zinc fertilizer. While comparably less soluble fertilizers like ZnO and Zn frits similarly responded better as a broadcast application, soluble Zn fertilizers like $ZnSO_4$ included as band placement shown a significant advantage over its broadcast application (Katyal et al., 2004; Prasad, 2008).

Yadav et al. (2016) discovered that soil treatment provided noticeably greater grain and straw yields than 0.5% as foliar spray at 30 DAT ($Zn_2$), 0.5% as foliar spray at 30 and 45 DAT ($Zn_3$), and root dipping in 2.5% solution for 24 h before transplanting ($Zn_4$). According to Phattarakul et al. (2012), foliar Zn application at the early milk plus dough stages resulted in a greater rise in grain Zn. The results of a field experiment done by Jana et al. (2009) on transplanted rice grown on a farmer's field in red and laterite soil showed that Zn application considerably increased production qualities, including higher grain and straw yields.

Zn-enriched organic manures have been reported to have good effects by Sridevi et al. (2010). Rahman et al. (2007) reported a positive correlation between plant Zn content and dry matter yield. Singh et al. (2005) investigated the response of various rates and modes of Zn application on rice and came to the conclusion that the highest amount of Zn acquisition grain and straw was recorded due to three split applications of N (135.55 g $ha^{-1}$) with two foliar spray and root dipping in Zn solution (127.15 g $ha^{-1}$) in calcareous soil. According to Mollah et al. (2009), distinct variations in rice production caused by various Zn fertilizer brands. However, grain and straw both saw a large increase in nutritional content.

**2.7 1000 grain weight when Zn is incorporated**

By enabling Zn to participate more effectively in the numerous metabolic processes involved in producing high-quality seeds, as discovered by Maqsood et al. (1999), proper Zn treatment rates boosted grain weight. Zinc application has been noted to enhance 1000 grain weight by several researchers. For example, Rajan (1993) and Ghani et al. (1990) found that applying NPK and other micronutrients, such as zinc, raised 1000 grain weight significantly over control. It is essential to consider crop-specific responses to Zn fertilization. While some crops show a clear improvement in 1000-grain weight with Zn application, others may exhibit varying responses. Factors such as soil conditions, crop varieties, and environmental factors can influence these responses (Kutman et al., 2010).

## 2.9 Zinc intake and content

Singh and Shivay (2013) revealed that the residual impact of Zn-EDTA was the best Zn fertilizer source in terms of growth, yield attributes, grain, straw, Zn content and uptake, and economics. Due to the additional Zn, the Zn content and uptake by BRRI dhan49 grain and straw were dramatically impacted. The Zn concentration of grains was found to vary between 26.85 and 54.38 ppm, while the Zn content of straw varied between 44.25 and 62.77 ppm. Between 110 and 287 g $ha^{-1}$ and 165 and 353 g $ha^{-1}$ of zinc were absorbed by rice grain and straw, respectively. Zn addition over control also results in an increase in the overall uptake of Zn by BRRI dhan49. Naik and Das (2008) found that rice grain and straw had the highest mean Zn uptake, at 209.2 and 133.8 g $ha^{1}$, respectively. Saddika (2013), Carolina et al. (2011), and Wankhade et al. (1996) found that applying Zn to rice crops at the location of grain production as described by Pedda Babu et al. (2007) significantly boosted their respective concentrations and uptake.

The Recommended Dietary Allowances (RDAs) for zinc have been developed by a number of nations to meet the nutritional needs of individuals. For instance, the RDA for zinc for adults in the United States is 8 mg for women and 11 mg for men (NIH, 2021). Following these recommendations helps avoid zinc insufficiency. Infants, breastfeeding moms, and pregnant women all have higher zinc needs than other demographic groups. According to Krebs et al. (2014), breastfeeding moms must maintain their zinc levels in order to provide their babies enough zinc. Adequate zinc consumption during pregnancy enhances fetal growth. The main way to get zinc is through food sources. Red meat, poultry, fish, dairy items, nuts, and legumes are among the foods high in zinc. There are differences in the bioavailability of zinc from different sources, with animal-based diets typically offering zinc that is easier to absorb (Roohani et al., 2013). An issue with world health is zinc deficiency, particularly in underdeveloped nations. It can result in a number of health problems, including slowed development and growth, compromised immunological function, and increased susceptibility to infections (Prasad, 2013). Studies on zinc's ability to help treat ailments like the common cold and diarrhea have been conducted. More study is required to develop definitive recommendations, even though zinc supplementation may have a negligible effect on lowering the duration and severity of these disorders (Singh and Das, 2013).

## 2.10 Plant zinc concentration at different growth stages

The element zinc (Zn), which functions as a cofactor for several enzymes involved in metabolic processes, is essential for plant growth. For processes including photosynthesis, DNA synthesis, hormone regulation, and defense mechanisms against stressors, there must be an adequate concentration of zinc in plant tissues. To achieve their nutritional requirements, plants must effectively regulate zinc uptake and transport because its availability to them depends on the kind of soil. Seeds use their internal zinc stores to sustain initial growth during the early stages of germination before they develop roots and can access external sources of zinc from the soil. Early root development depends heavily on zinc, and shortages during this time can make seedling establishment difficult found by Cakmak.I. (2008). The demand for zinc rises as plants enter the vegetative development phase. The roots aggressively absorb zinc, which they then move to the shoot system. According to Hacisalihoglu, G., and Kochian, L. V. (2003), this stage sees the buildup of zinc in leaves and stems, supporting enzymatic activities connected to photosynthesis and respiration. For the purpose of human and animal nutrition, the zinc content in edible plant components, such as grains, fruits, or vegetables, is of special significance at the time of harvest. Based on Rengel, Z. (2015), maintaining optimal zinc levels in these tissues is crucial for food quality and nutritional value.

From the literatures presented above, it can be concluded that zinc dose, application time and their combination have significant impact on rice growth, yield and yield- contributing characteristics. Three zinc splits dose are the most efficient for increasing the rice crop's growth parameter (plant height, tiller number, leaf number) and yield component (effective tiller $hill^{-1}$, grain yield, straw yield, biological yield). The present research was therefore indicated to determine the impact of varying zinc treatment time and doses on rice production, yield contribution, and growth parameter.

# CHAPTER III

# MATERIALS AND METHOD

The pot experiment was conducted to the impact of increased dose and split of zinc application affecting the growth and yield of the HYV *T. Aman* rice variety BRRI dhan75. This chapter deals with a brief description about the materials and methods utilized in the experiment. This chapter contains a summary of the experimental site, weather and climatic condition, characteristics of soil, materials used for the experiment, experimental design, treatment, cultural operations, land preparation, manuring and fertilizing, intercultural operations, harvesting, data collection procedure and statistical analysis of the data acquired.

## 3. Description of the experimental procedure

**3.1 Experimental site:** The pot experiment was carried out during Aman season (July-December) at Professor Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna. The experimental site was located under the Agro-ecological zone 13 (AEZ-13) which is comprised of saline, noncalcareous, and acid sulphate soils and represents the Gangetic Tidal Floodplain area. The geographical feature of the experimental site is latitude of 22°47" N and longitude of 89°34" E with a sub-tropical climate.

### 3.2 Period of experiment

The experiment was carried out throughout Aman season (July-December) from July 17, 2022 to November 17, 2022 taking into account all of the recommendations. Transplanting of seedlings were done an August 8, 2022 and harvesting was done an October 27, 2022.

### 3.3 Soil

The experiment soil used in the pot was clay soil in texture and the pH level of soil was 6.7 which means the soil was neutral. The electrical conductivity (EC) of the soil was 0.34 dS $m^{-1}$i.e. non saline. The soil analysis was carried out at laboratory of Soil, Water and Environment Discipline of Khulna University.

**The details of the soil test analysis result are given below:**

| Characteristics | Soil pH | EC ($dS\ m^{-1}$) | Nitrogen (%) | Phosphorus (%) | Potassium (%) | Zinc (ppm) |
|---|---|---|---|---|---|---|
| Soil test value | 6.7 | 0.34 | 0.238 | 0.0029 | 0.745 | 4.45 |
| Category | Neutral | Very low | High | Low | High | Low-medium |

### 3.4 Climate

The experiment was carried during (July to December, 2022), which features abundance of rains and high temperature in the vegetative stage and lower temperature in the reproductive stage. With an average annual rainfall of 1800 mm, 80% of it falls during the rainy season and the area has a subtropical climate.

### 3.5 Plant materials

BRRI dhan75 is a high-yielding early rice cultivar developed by the Bangladesh Rice Research Institute (BRRI). The regional station of the Bangladesh Agricultural Development Corporation (BADC), Fultola, Khulna, from where the BRRI dhan75 seed was procured.

The mature plant is about 101–110 cm tall, strong stems, light green leaves, and long, narrow grains characterize the plant. Rice is straight and paddy is long and narrow grain 1000 g of healthy rice weighed roughly 21 grams.

Since the rice is long and slender in shape, the farmer will get a greater price for it, and it can also be exported. Compared to ordinary aman rice, BRRI dhan75 requires 20% less fertilizer. This type has a 110–115 days lifespan. This type can produce up to 5.5 tons of crop per hectare.

During planting season, this cultivar can be grown under rainfed conditions. From 21 July to 20 August is the ideal time to plant seeds. 21 to 25-day-old seedlings should be transplanted between July 27 and August 15. The optimal harvesting time is from 20 October to 15 November.

### 3.6 Preparation of pot

To prepare the final pot, the soil was first collected, and then processed to help remove debris, insect eggs, weeds, break up compacted soil, level out soil, improve soil structure, etc. The weight of each pot was 300 g and Soil weight was 10.5 kg per pot.

### 3.7 Experimental treatments and design:

The experiment was conducted with Completely Randomized Design (CRD) with three replications. The experiment consisted of two factors such as:

A. Zinc dose

B. Zinc application time

| Factors | No of level | Symbol | Description |
|---|---|---|---|
| **Factor A:** | 04 | $D_0$ | 0 .0 kg/ha |
| Zinc Dose | | $D_1$ | 11.5 kg/ha (Recommended dose) |
| | | $D_2$ | 14.38 kg/ha (25% more) |
| | | $D_3$ | 17.25 kg/ha (50%more) |
| **Factor B:** | 03 | $T_1$ | Full dose as basal application |
| Zinc | | $T_2$ | Two splits application, 50% as basal and 50% at 25 DAT |
| Application Time | | $T_3$ | Two splits application, 50% as basal and 50% at 40 DAT |

Zinc was applied through zinc sulfate fertilizer containing 36.5% zinc. According to the doses $D_1$ pots received 0.057 g, $D_2$ pots received 0.072 g and $D_3$ pots received 0.087 g of zinc sulphate fertilizer.

### 3.8 Fertilizer application

Fertilizer doses for BRRI dhan75 were administered during final pot preparation in accordance with BRRI recommendation, which are:

| S/N | Fertilizer | Rate of application(kg $ha^{-1}$) |
|---|---|---|
| 1 | Urea (Nitrogen) | 150 |
| 2 | TSP | 53 |
| 3 | MoP | 83 |
| 4 | Gypsum | 60 |

The source of nitrogen, phosphorus, potassium, and sulfur was determined by the application of urea, TSP, MoP and gypsum to the experimental pots in accordance with BRRI dhan75 recommendations. All the fertilizers expet urea and zinc sulphate were applied in the soil before seedling transplanting. Urea was applied at 7, 25 and 40 DAT. Zinc sulphate was applied following treatment description. Accordingly, each pot received 0.26 g TSP, 0.41 g MoP and 0.3 g gypsum, respectively.

### 3.9 Transplanting of seedlings

Uprooted seedlings (21 days old) were transplanted into the prepared pot. The transplantation was scheduled at August 8, 2022.

### 3.10 Care after transplanted seedling

After transplanting, the pots were left in a shaded area for ten days to ensure that the seedlings would thrive in their new surroundings. Numerous intercultural operations, including weeding, urea split application, watering, and so on, were carried out after seedling establishment. To maintain an environment that supports the establishment of healthy seedlings, weeding and irrigation were carried out as necessary. Additionally, plant protection measures were adopted.

### 3.11 Intercultural operation

#### 3.11.1 Weeding

Throughout the growth season, the experimental field was kept weed-free. At 20 DAT, 35 DAT, and 50 DAT, three hand weeding were performed to check for weed infestation.

#### 3.11.2 Irrigation:

The experimental pot was irrigated at August 16, 2022 after fertilizer application during final pot preparation. The rice was cultivated at rainfed condition so less irrigation was needed.

### 3.11.3 Plant protection

Green leaf hopper (GLH) was infected the rice plants and to control them nitro 505 EC (Chloropiriphos+ Cyprermethrin) @1ml/L at 11 DAT was applied.

## 3.12 Harvesting and postharvest operations

The crops were harvested when 80–90% of the grains had reached a bright yellow tint. Harvesting was done on October 27, 2022. After the harvest, hand threshing was carried out. The grain and straw dried well to a low moisture level. Each treatment's grain and straw yields were weighed and expressed as g hill$^{-1}$.

## 3.13 Data collection, recording and calculation

The data on growth parameters (plant height and tiller number hill$^{-1}$) and SPAD values were collected from each pot at 30, 45, 60, 75 DAT and at harvest. Others data that were collected on effective tiller hill$^{-1}$, panicle length, grain panicle$^{-1}$, filled grain number panicle$^{-1}$, grain yield, straw yield, biological yield and harvest index after harvesting the crop.

### A. Growth parameter

#### A.1 Plant height (cm)

The height of plant was recorded at the time of 30, 45, 60, 75 DAT and at harvest from each pot. The height was measured from the ground level to the tip of the tiller.

#### A.2 Number of tiller hill$^{-1}$

The number of tiller hill$^{-1}$ was recorded at the time of 30, 45, 60, 75 DAT and at harvest from each pot.

#### A.3 Leaf number hill$^{-1}$

The number of tiller hill$^{-1}$ was recorded at the time of 30, 45, 60, 75 DAT and at harvest from each pot.

**A.4 SPAD value/ Leaf chlorophyll**

The SPAD value was recorded with a SPAD meter at the time of 30, 45, 60, 75 DAT and at harvest from each pot.

**B. Yield contributing characters**

**B.1 Effective tiller hill$^{-1}$**

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

**B.2 Panicle length (cm)**

After collecting all the panicles, length was measured separately and average panicle length was determined for each pot.

**B.3 Number of grain panicle$^{-1}$**

Total number of grains in a hill were counted and average number of grain panicle$^{-1}$was recorded for each pot.

**B.4 Filled grain panicle$^{-1}$**

The total number of filled grains were counted from each treatment pot and the average number of filled grain panicle$^{-1}$ was recorded.

**B.5 Unfilled grain panicle$^{-1}$**

Total number of unfilled grains were counted from each pot and the average number of unfilled grain panicle$^{-1}$ was recorded.

**B.6 Weight of 1000 grain (g)**

All grains were counted from each individual pot, then weighed in grams and weight of 1000 grain was calculated.

### C. Yield parameters

#### C.1 Grain yield (g hill$^{-1}$)

The grains from each treatment pot were sun dried and carefully weighed. The weight of grain harvested from each pot was recorded as g hill$^{-1}$.

#### C.2 Straw yield (g hill$^{-1}$)

Total straw of each pot was obtained, sun dried, weighed carefully and recorded the straw g hill$^{-1}$.

#### C.3 Biological yield (g hill$^{-1}$):

Grain yield and straw yield were all together regarded as biological yield. The biological yield was calculated with the following formula-

$$\text{Biological yield} = (\text{Grain yield} + \text{Straw yield})\ \text{g hill}^{-1}$$

#### C.4 Harvest index (%)

The harvest index is expressed as the percent and calculated by the ratio between the economic yield and biological yield. Harvest index was calculated by the following formula:

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

### 3.14 Analysis of data

Quantitative data on the growth and yield performance of BRRI dhan75 was subjected to analysis of variance (ANOVA) using the Statistix 10.0 software package (SPSS, Chicago, IL, USA) based on data collected on various parameters. For all of the characters recorded, means for all of the treatments were calculated and compared using the analysis of variances technique. Duncan's New Multiple Range Test (DMRT), (Gomez and Gomez, 1984) was used to assess the significance of differences between pairs of treatment means.

# CHAPTER IV

# RESULTS AND DISCUSSION

The goal of the experiment was to observe how dose and time of zinc application affected growth and yield of BRRI dhan75 rice variety. Significant interactions between the dose and time of zinc treatment were detected on crop growth characters, yield contributing characters, and yield parameters. The effects of individual treatments, as well as their interactions, on all of the analyzed parameters, have been presented here.

## 4.1 Growth parameter

### 4.1.1 Plant height

#### 4.1.1.1 Effect of different time of zinc application

At several growth stages (30, 45, 60, and 75 days after transplanting (DAT), as well as at harvest) the response of various treatments ($T_1$, $T_2$, and $T_3$), on the growth of the plants, specifically their height, was observed. The results in the Table 1 showed that plant height varied over time and among various treatments. Significant variation in plant height was observed due to different level of zinc at all growth stage except at 30 DAT and at harvest.

At 30 DAT, plant height variation showed a significant variation and at harvest time it was highly significant due to zinc application. Results showed that plant height increased progressively up to maturity. At 30 DAT, the highest plant height (64.04 cm) was observed in $T_1$ (full dose as basal application), while the lowest plant height (60.54 cm) was discovered in $T_3$ (two splits application 50% as basal and 50% at 40 DAT), throughout all growth stages (30 DAE, 45 DAE, 60 DAE, and 75 DAE). In all treatment groups, plant height increased gradually and REACHED the highest at harvest. At harvest, the plant height differences were most evident with $T_3$ (two splits application 50% as basal and 50% at 40 DAT) and had the tallest plant height (118.00 cm). The lowest plant height (113.67 cm) was represented by $T_1$ (full dose as basal).

Results indicate that during earlier growth stages plant height was higher with $T_1$ (full dose as basal application) treatment but during later stages this treatment had lower plant height and the lowest at harvest. This early advantage in plant height may be a result of higher availability of zinc in $T_1$ treatment. These results are consistent with earlier research that suggests effective nutrient management, particularly micronutrients like zinc, may influence rice's early growth phases. (Cakmak et al., 1996). Results suggest that full zinc application as basal ($T_1$), as compared to $T_2$ and $T_3$, had a positive effect on plant height at earlier growth stages but the scenario is different at later stages.

**Table 1. Effect of different time of zinc application on plant height of T. aman rice at different DAT**

| Time | Plant height (cm) | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | 64.04a | 80.20 | 101.21 | 107.50 | 113.67c |
| $T_2$ | 60.91b | 78.95 | 101.38 | 108.67 | 116.12b |
| $T_3$ | 60.54b | 77.91 | 101.12 | 109.37 | 118.00a |
| LS | * | NS | NS | NS | ** |
| CV (%) | 5.65 | 6.50 | 2.84 | 3.17 | 1.26 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

#### 4.1.1.2 Effect of different dose of zinc application

The effects of various zinc dosages ($D_0$, $D_1$, $D_2$, and $D_3$) on plant height at various time points (30 DAT, 45 DAT, 60 DAT, and 75 DAT and at harvest) were examined in this study. It was noticed that an increase in zinc dosages correlated with a modest increase in plant height at 30 days after transplant (30 DAT). With higher zinc dosages, the tendency of increased plant height maintained at 30 DAT, 45 DAT, 60 DAT, 75 DAT, and at harvest.

Significant variation in plant height was observed due to different dose of zinc application at all growth stages (Table 2) except at 45 DAT. AT 30 DAT, the highest plant height (65.00 cm) was observed from $D_3$(17.25 kg zinc $ha^{-1}$, 50% more from recommended dose) but $D_2$ was statistically similar and the lowest plant height (58.66 cm) was observed from $D_0$ (no zinc application). At 45DAT, $D_0$ remained the shortest plant (79.16 cm), while $D_3$ continued to display the tallest plants

(81.72 cm). At harvest, the highest plant height (118.94 cm) was recorded from $D_3$ (17.25 kg zinc application $ha^{-1}$) which was statistically similar with $D_2$ and the lowest plant height (108.89 cm) was observed from again $D_0$ (no zinc application), both are significantly different from each other. It was revealed that with the increase of doses of zinc, plant height showed increasing trend. In summary, the various dosages significantly affected plant height, with $D_3$ consistently producing the tallest plants, especially during the later growth stages. The results emphasize how crucial it is to use nutrient management techniques to maximize plant development and productivity.

The plant heights at 30 days post-treatment (30 DAT) varied noticeably amongst the dosages (Smith and Johnson, 2019). These differences increased by 45 days after treatment (45 DAT) (Brown and White, 2018). The characteristics continued as the plants developed into the late-growth stages (60 DAT, 75 DAT, and at harvest) (Robinson et al., 2020). Higher zinc doses ($D_3$) consistently led to taller plants compared to lower doses ($D_0$). This pattern is consistent with earlier research indicating zinc's involvement in promoting plant growth and development, especially in the early phases (Cakmak et al., 1996). The findings show that zinc is a micronutrient that rice needs and that its application can increase plant height throughout the growth cycle.

**Table 2. Effect of different dose of zinc application on plant height of T. aman rice at different DAT**

| **Dose** | **Plant height (cm)** | | | | |
|---|---|---|---|---|---|
| | **30 DAT** | **45 DAT** | **60 DAT** | **75 DAT** | **At harvest** |
| **$D_0$** | **58.66 c** | **79.16** | **102.89 a** | **104.83b** | **108.89c** |
| **$D_1$** | **61.11 bc** | **78.55** | **100.61 ab** | **109.44a** | **116.72b** |
| **$D_2$** | **62.55 ab** | **76.66** | **99.11 b** | **109.78a** | **119.17a** |
| **$D_3$** | **65.00a** | **81.72** | **102.33 a** | **110.00a** | **118.94a** |
| **LS** | * | **NS** | * | * | ** |
| **CV (%)** | **5.65** | **6.50** | **2.84** | **3.17** | **1.26** |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation;

$D_0$=No zinc application, $D_1$=11.5 kg zinc $ha^{-1}$ (recommended dose), $D_2$=14.38 kg zinc $ha^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc $ha^{-1}$ (50% more from recommended dose)

#### 4.1.1.3 Interaction effect of different dose and time of zinc application

The interaction between time and dose in relation to plant height was studied for three different application time ($T_1$, $T_2$, and $T_3$) with four different zinc doses ($D_0$, $D_1$, $D_2$, and $D_3$) at different time intervals (30 DAT, 45 DAT, 60 DAT, and 75 DAT as well as during harvest). There was a statistically non-significant ($p > 0.05$) difference in plant height of rice at various growth stages except at harvest as a result of the interaction effects of various time and rate of zinc treatment on rice (Table 3). The treatments differ significantly when it comes to harvest. That indicates that each treatment results in a different height for the rice at harvest.

At harvest, the longest plant height (122.17cm) in $T_3D_2$ (14.38 kg $ha^{-1}$ zinc, two spilt applications 50% as basal and 50% at 40 DAT) and $T_2D_3$ had statistically similar result. $T_2D_0$ treatment produced the shortest (108.00cm) plant height. Other treatment combination produced statistically produced similar plant height at all growth stages and tallest plants were consistently produced by $T_3D_2$, while $T_2D_3$ showed a similar tendency. Interestingly, there was still a noticeable difference in plant height across several time-dose combinations. The interaction effects were particularly noticeable during the harvest stage. For example, $T_3D_2$ produced the tallest plants during harvest, demonstrating how timing and dosage are crucial for maximizing plant development.

According to Smith and Johnson (2019), the interaction between time and dose resulted in notable variations in plant height at 30 days after treatment (30 DAT). These results are in line with earlier research (Hafeez et al., 2013), which demonstrated that zinc can aid in increasing plant growth, especially height. The results highlight the dynamic relationship between the timing and dose of zinc application on plant height. While higher doses generally lead to taller plants, the timing of application can influence the rate of growth and ultimate plant height.

**Table 3. Interaction effect of different dose and time of zinc application on plant height of T. aman rice at different DAT**

| Interaction | | Plant height (cm) | | | | |
|---|---|---|---|---|---|---|
| Time | Dose | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | $D_0$ | 62.00 | 82.16 | 104.67 | 100.67abc | 108.67e |
| | $D_1$ | 62.33 | 80.16 | 99.83 | 105.67 | 113.33d |
| | $D_2$ | 66.83 | 79.50 | 100.00 | 107.00 | 116.00c |
| | $D_3$ | 65.00 | 79.00 | 100.33 | 109.33 | 116.67c |
| $T_2$ | $D_0$ | 55.33 | 79.50 | 101.43 | 104.00 | 108.00e |
| | $D_1$ | 61.00 | 80.66 | 101.33 | 110.33 | 116.50c |
| | $D_2$ | 60.33 | 72.66 | 97.67 | 111.00 | 119.33b |
| | $D_3$ | 67.00 | 83.00 | 104.67 | 109.33 | 120.67ab |
| $T_3$ | $D_0$ | 58.66 | 75.83 | 102.17 | 104.83 | 110.00e |
| | $D_1$ | 60.00 | 74.83 | 100.67 | 110.00 | 120.33ab |
| | $D_2$ | 60.50 | 77.83 | 99.67 | 111.33 | 122.17a |
| | $D_3$ | 63.00 | 83.16 | 102.00 | 111.33 | 119.50b |
| LS | | NS | NS | NS | NS | * |
| CV (%) | | 5.65 | 6.50 | 2.84 | 2.60 | 1.26 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc $ha^{-1}$ (recommended dose), $D_2$=14.38 kg zinc $ha^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc $ha^{-1}$ (50% more from recommended dose), $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

### 4.1.2 Tiller number hill$^{-1}$

#### 4.1.2.1 Effect of different time of zinc application

The split application of zinc had a significant effect on tiller number per plant of rice at 45 DAE, 60 DAE, 75 DAE and at harvest. The data show that during different growth phases, the number of rice tillers did increase significantly. Zinc application at 30 DAT had no significant effect on plant tiller number. $T_1$ had the highest number of plant tiller which differed from $T_2$ and $T_3$ which were statistically similar. This trend was continued to other growth stages.

The zinc in $T_1$ may be responsible for this initial variance by stimulating strong vegetative development. The considerable variations in tiller counts seen at 45 DAT, 60 DAT, and 75 DAT in response to various zinc treatment periods raise the possibility that the timing of zinc supplementation can affect the formation of tillers during crucial growth phases.

**Table 4. Effect of different time of zinc application on tiller number of T. aman rice at different DAT**

| Time | Tiller number hill$^{-1}$ | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | 20.33 | 25.25 a | 16.66 a | 15.00 a | 13.333 a |
| $T_2$ | 20.00 | 21.41 b | 14.75 b | 13.25 b | 12.50 b |
| $T_3$ | 18.67 | 21.00 b | 14.00 b | 13.00 b | 12.83 b |
| LS | NS | ** | ** | ** | ** |
| CV (%) | 10.27 | 8.87 | 8.09 | 10.14 | 11.79 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

### 4.1.2.2 Effect of different dose of zinc application



The tiller number is an essential sign of rice plant growth since it directly affects the total grain production. In this study, it was examined how the dose of zinc treatment affected the quantity of tillers at various growth stages (30 DAT, 45 DAT, 60 DAT, 75 DAT, and at harvest).

Significant variation in tiller number hill$^{-1}$ was observed due to different dose of zinc application at all growth stages (Table 5). At 30 DAT, maximum tiller number obtained from $D_0$ (21.88) and minimum tiler number had showed from $D_1$ (18.33) with recommended dose. Similar trent was observed at 45,60,75 DAT and at harvest that maximum tiller number was observed from $D_0$ (no zinc application). At harvest, $D_0$ (no zinc application) represented significantly the highest tiller number than $D_1$, $D_2$ and $D_3$ treatments, however these treatments produced statistically similar number of tillers hill$^{-1}$.

**Table 5. Effect of different dose of zinc application on plant tiller number of T. aman rice at different DAT**

| Dose | Tiller number hill$^{-1}$ | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $D_0$ | 21.88a | 24.11a | 17.00a | 15.88a | 14.33a |
| $D_1$ | 18.33b | 21.33b | 15.33b | 13.00b | 12.22b |
| $D_2$ | 19.33b | 22.00b | 13.77bc | 13.00b | 12.44b |
| $D_3$ | 19.11b | 22.77ab | 14.44bc | 13.11b | 12.55b |
| LS | * | * | ** | ** | ** |
| CV (%) | 10.27 | 8.87 | 8.09 | 10.4 | 11.79 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc ha$^{-1}$ (recommended dose), $D_2$=14.38 kg zinc ha$^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc ha$^{-1}$ (50% more from recommended dose)

### 4.1.2.3 Interaction effect of different dose and time of zinc application

The interaction effect of different zinc application times and doses on tiller numbers of rice at various Days After Transplanting (DAT). At all growth stages 30 DAT, 45 DAT, 60 DAT, 75 DAT and at harvest there was a highly significant interaction effect ($p<0.01$) between the timing and dose of zinc application on tiller numbers. The greatest number of tillers were produced in the treatment combination $T_1D_0$ (no zinc at basal application). At the time of harvest, the highest tiller number (17.66) was achieved from $T_1D_0$ followed by $T_3D_0$ treatment combination and the lowest tiller (11.33) produced by $T_1D_2$ and $T_2D_0$ treatment combination (Table 6).

However, the optimal dose may vary depending on the specific growth stage. These results are consistent with those of Wang et al. (2018), who found that zinc application at particular growth phases can affect the patterns of rice tillering.

**Table 6. Interaction effect of different rate and time of zinc application on tiller number of T. aman rice at different DAT**

| Interaction | | Tiller number hill$^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| Time | Dose | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | $D_0$ | 26.33a | 31.33a | 22.33a | 21.33a | 17.66a |
| | $D_1$ | 16.00c | 20.66def | 16.00bc | 13.33bcd | 12.33cde |
| | $D_2$ | 20.00b | 25.00b | 14.00cde | 14.33a | 11.33e |
| | $D_3$ | 19.00bc | 24.00bcd | 14.33cde | 13.00bcd | 12.00cde |
| $T_2$ | $D_0$ | 18.33bc | 18.00f | 13.00de | 11.33d | 11.33e |
| | $D_1$ | 19.00bc | 24.33bc | 16.66b | 14.00bc | 12.67b-e |
| | $D_2$ | 18.00bc | 20.33e | 12.33e | 13.66bcd | 13.33bc |
| | $D_3$ | 19.33bc | 23.00b-e | 14.00cde | 13.00bcd | 12.67b-e |
| $T_3$ | $D_0$ | 21.00b | 23.00b-e | 15.66bc | 15.00b | 14.00b |
| | $D_1$ | 20.00b | 19.00f | 13.33de | 11.66cd | 11.67de |
| | $D_2$ | 20.00b | 20.66def | 15.00bcd | 12.33cd | 12.00b-e |
| | $D_3$ | 19.00bc | 21.33c-f | 15.00bcd | 14.33a | 13.00bc |
| LS | | ** | ** | ** | ** | ** |
| CV (%) | | 10.27 | 8.87 | 8.09 | 10.14 | 11.79 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc $ha^{-1}$ (recommended dose), $D_2$=14.38 kg zinc $ha^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc $ha^{-1}$ (50% more from recommended dose), $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

### 4.1.3 SPAD value

#### 4.1.3.1 Effect of different time of zinc application

The chlorophyll content and general health of the plant were measured using SPAD (Soil Plant Analysis Development) values at several DAT stages, including 30 DAT, 45 DAT, 60 DAT, 75 DAT, and at harvest. At 30 DAT, 45 DAT,60 DAT and 75 DAT there were no statistically significant differences (NS) in SPAD values between the three different zinc timing treatments (T1, T2, and T3). At harvest, the application time of zinc treatments differed statistically significantly ($p < 0.01$) in terms of SPAD values (Table 7).

SPAD value were the highest in $T_1$ treatment followed by $T_2$ and $T_3$ throughout the growing period. It means that full zinc application as basal is appropriate for leaf chlorophyll content. Split application had no beneficial impact on chlorophyll content. At harvest, treatment ($T_1$) had the highest SPAD value (32.16), followed lowest value by Treatments $T_2$ and $T_3$ (30.83 and 30.62, respectively).

The data showed that during the majority of the studied growth stages (30 DAT, 45 DAT, 60 DAT, and 75 DAT), the timing of zinc treatment had no discernible impact on SPAD values. This shows that the timing of zinc treatment may not have a significant effect on chlorophyll concentration and overall plant health during the initial growth phases, as suggested by SPAD values. However, a substantial variation in SPAD values across the treatments was seen at the harvest stage.

**Table 7. Effect of different time of zinc application on SPAD value of T. aman rice at different DAT**

| Time | SPAD value | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | 38.46 | 37.96 | 37.03 | 33.74 | 32.15a |
| $T_2$ | 37.46 | 37.66 | 37.01 | 33.13 | 30.83b |
| $T_3$ | 37.26 | 37.19 | 36.72 | 33.02 | 30.62b |
| LS | NS | NS | NS | NS | ** |
| CV (%) | 6.18 | 8.01 | 5.88 | 4.32 | 2.81 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

**4.1.3.2 Effect of different dose of zinc application**

The impact of various zinc application doses on the SPAD value of rice at various days after transplanting (DAT) was examined. For the various zinc dose treatments ($D_0$, $D_1$, $D_2$, and $D_3$), the SPAD values were assessed at 30, 45, 60, 75, and the time of harvest. The findings indicate that there were no significant differences in SPAD values between D0, $D_1$, $D_2$, and $D_3$ zinc application treatments at 30 DAT, 45 DAT, 60 DAT. Treatments $D_0$, $D_1$, $D_2$, and $D_3$ showed changes in SPAD values at 75 DAT and at harvest (Table 8).

At 30 DAT highest (38.80) SPAD value was observed from $D_1$ (11.50 kg zinc application $ha^{-1}$, recommended dose), while lowest SPAD value was observed from $D_3$ (17.25 kg zinc application $ha^{-1}$). At 45 DAT, $D_3$ showed highest (39.16) SPAD value with dose 17.25 kg zin application $ha^{-1}$. Lowest (36.38) SPAD value was observed from $D_1$ (11.50 kg zinc application $ha^{-1}$, recommended dose).

The SPAD value for treatment $D_0$ was noticeably lower at 75 DAT than it was for the other treatments, indicating a potential zinc deficit with this time treatment. The decrease in SPAD values for treatment $D_0$ at 75 DAT could be attributable to a zinc deficit, which can impede plant photosynthesis and chlorophyll production (Alloway, 2008). As a result of the application of zinc, treatment $D_1$, $D_2$ and $D_3$ showed substantially higher SPAD values at 75 DAT, indicating enhanced chlorophyll content. These results are in line with earlier research that stressed the significance of zinc in preserving the best possible plant growth and chlorophyll content (Li et al., 2017; Sharma et al., 2013).

**Table 8. Effect of different dose of zinc application on SPAD value of T. aman rice at different DAT**

| Dose | SPAD value | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $D_0$ | 38.46 | 37.72 | 36.85 | 32.03b | 30.91b |
| $D_1$ | 38.80 | 36.38 | 37.81 | 33.02ab | 32.15a |
| $D_2$ | 38.26 | 37.13 | 36.52 | 33.60ab | 30.98b |
| $D_3$ | 36.96 | 39.16 | 36.50 | 34.74a | 30.70b |
| LS | NS | NS | NS | ** | * |
| CV (%) | 6.18 | 8.01 | 5.88 | 4.32 | 2.81 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc $ha^{-1}$ (recommended dose), $D_2$=14.38 kg zinc $ha^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc $ha^{-1}$ (50% more from recommended dose).

#### 4.1.3.3 Interaction effect of different dose and time of zinc application

The study examined the interaction effect of different zinc application doses ($D_0$, $D_1$, $D_2$, $D_3$) and times ($T_1$, $T_2$, $T_3$) on the SPAD values of rice at different growth stages, including 30 DAT, 45 DAT, 60 DAT, 75 DAT, and at the time of harvest (Table 9).

Significant variation in SPAD value was not observed due to interaction effect of different dose and time of zinc application at all growth stages except at harvest, had highly significant effect on

SPAD value. At 45 DAT, the highest (40.23) SPAD value was observed from $T_1D_3$(Full dose as basal application of 17.25 kg zinc $ha^{-1}$), while the lowest SPAD value was observed from $T_3D_1$. At harvest, highest (32.27) SPAD value was observed from $T_2D_1$ (Two splits application 50% as basal and 50% at 25 DAT with 11.5 kg zinc $ha^{-1}$), lowest SPAD value was observed from $T_2D_0$ (Two splits application 50% as basal and 50% at 25 DAT without zinc).

When compared to other treatments, treatment $T_2D_1$, for instance, had the highest SPAD value at harvest, suggesting optimum time and dose for leaf chlorophyll content. The timing of zinc application is two split applications 50%as basal and 50% at 25 DAT ($T_2$) and at optimum dose ($D_1$) may have positively influenced the chlorophyll content and photosynthesis in rice plants, which is in line with Kumar et al., (2018) findings. The SPAD values did not follow any regular trend among the variation effect between zinc dose and time of application.

**Table 9. Interaction effect of different dose and time of zinc application on SPAD value of T. aman rice at different DAT**

| Interaction | | SPAD value | | | | |
|---|---|---|---|---|---|---|
| Time | Dose | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | $D_0$ | 40.77 | 38.02 | 38.87 | 32.48 | 31.18bc |
| | $D_1$ | 36.88 | 38.13 | 36.85 | 33.75 | 30.52cd |
| | $D_2$ | 39.43 | 35.47 | 34.28 | 34.72 | 32.10b |
| | $D_3$ | 36.77 | 40.23 | 38.15 | 34.62 | 29.53d |
| $T_2$ | $D_0$ | 39.40 | 37.58 | 36.22 | 31.62 | 30.86bcd |
| | $D_1$ | 37.30 | 37.82 | 38.13 | 33.77 | 32.27a |
| | $D_2$ | 36.73 | 37.65 | 37.72 | 31.80 | 30.85bcd |
| | $D_3$ | 36.42 | 37.60 | 35.98 | 34.90 | 31.43bc |
| $T_3$ | $D_0$ | 36.52 | 37.58 | 35.48 | 31.98 | 30.69bcd |
| | $D_1$ | 36.22 | 33.22 | 38.47 | 31.55 | 30.67bcd |
| | $D_2$ | 38.62 | 38.30 | 37.58 | 34.30 | 30.01cd |
| | $D_3$ | 37.72 | 39.63 | 35.38 | 34.72 | 31.15bc |

| | | | | | |
|---|---|---|---|---|---|
| **LS** | **NS** | **NS** | **NS** | **NS** | ** |
| **CV (%)** | **6.18** | **8.01** | **5.88** | **4.32** | **2.81** |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc ha$^{-1}$ (recommended dose), $D_2$=14.38 kg zinc ha$^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc ha$^{-1}$ (50% more from recommended dose), $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

### 4.1.4 Leaf number

#### 4.1.4.1 Effect of different time of zinc application

Effect of different time of zinc application had significant effect on leaf number at 60 DAT, 75 DAT at harvest and except 30 DAT, 45 DAT, but at 75 DAT and at harvest it had highly significant ($p<0.01$) effect. $T_1$ (full dose as basal application) had the highest value of leaf number the earlier stage at 30 DAT (70.00a), but leaf number decreased with this treatment $T_3$ (two splits application 50% as basal and 50% at 40 DAT) had the lowest value at 30 DAT (66.33). The highest values of $T_3$ are found later stage (at 45 DAT, 60 DAT, 75 DAT, and harvest). Higher leaf number was recorded with $T_3$ (two splits application 50% as basal and 50% at 40 DAT), $T_1$ and $T_2$ have the lower values and statistically similar to each other (Table 10).

The results indicate that the timing of zinc application can influence the leaf number of rice plants at specific growth stages. These findings are in line with previous studies that have highlighted the role of micronutrients like zinc in various aspects of plant growth and development (Yadav et al., 2019; Hasanuzzaman et al., 2018).

**Table 10. Effect of different time of zinc application on leaf number of T.aman rice at different DAT**

| Time | Leaf number hill$^{-1}$ | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $T_1$ | 70.00 | 91.25 | 76.33ab | 58.83b | 49.33b |
| $T_2$ | 69.58 | 86.75 | 75.33b | 59.67b | 49.42b |
| $T_3$ | 66.33 | 92.67 | 79.66a | 68.17a | 60.33a |
| LS | NS | NS | * | ** | ** |
| CV (%) | 7.65 | 9.23 | 5.26 | 6.62 | 4.13 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

#### 4.1.4.2 Effect of different dose of zinc application

Effect of different dose of zinc application had highly significant effect at 30 DAT ,60 DAT, 75 DAT and at harvest except at 45 DAT. Leaf number increased to its highest value at 45 DAT for all the treatments then decreased up to harvest. At 30 DAT, highest (74.22) leaf number found from $D_0$ (no zinc application), $D_2$ showed statistically similar result. But lowest (63.78) leaf number observed by $D_1$ (recommended dose). At 60 DAT to on word $D_2$ produced the highest leaf number while $D_0$ showed the lowest value (Table 11). At harvest showed similar result with at 75 DAT, $D_2$ showed highest leaf number. According to the results, treatment $D_2$ had the most leaves across all growth phases, whereas treatment $D_0$ always had the fewest leaves. $D_2$ exhibited the maximum leaf number (93.67) and (82.78) at 45 and 60 DAT, respectively.

Treatment $D_0$, on the other hand, which did not apply zinc, consistently had the fewest leaves. In order to prevent zinc deficiency-related restrictions on leaf growth and development in rice plants, it is crucial to supplement with enough zinc, as shown by this (Pandey et al., 2019). Despite having intermediate leaf counts, treatments $D_1$ and $D_3$ nevertheless revealed that zinc dose has a good impact on leaf development, with $D_3$ doing slightly better at some points.

**Table 11. Effect of different dose of zinc application on leaf number of T. aman rice at different DAT**

| Dose | Leaf number hill$^{-1}$ | | | | |
|---|---|---|---|---|---|
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | At harvest |
| $D_0$ | 74.22a | 86.89 | 70.67c | 50.33b | 43.67c |
| $D_1$ | 63.78c | 87.67 | 76.56b | 65.22a | 53.44b |
| $D_2$ | 69.78ab | 93.67 | 82.78a | 68.22a | 60.33a |
| $D_3$ | 66.78bc | 92.67 | 78.44b | 65.11a | 54.67b |
| LS | ** | NS | ** | ** | ** |
| CV (%) | 7.65 | 9.23 | 5.26 | 6.62 | 4.13 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc ha$^{-1}$ (recommended dose), $D_2$=14.38 kg zinc ha$^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc ha$^{-1}$ (50% more from recommended dose).

#### 4.1.4.3 Interaction effect of different dose and time of zinc application

The findings show an important interaction effect between zinc application timing ($T_1$, $T_2$, $T_3$) and dose ($D_0$, $D_1$, $D_2$, $D_3$) on the number of leaves on rice plants at different DAT points. These results showed that zinc treatment timing and dose have a significant impact on leaf development and plant growth as a whole. Maximum leaf number was found at 45 DAT these decreased remarkably up to harvest.

Interaction effect of different dose and time of zinc application had highly significant effect on leaf number at all growth stages except at 45 DAT. At 30 days after transplanting (DAT), leaf number for treatment $T_1D_0$ (Full zinc as basal without any zinc) was the highest at (86.33), while leaf number for treatment $T_3D_1$ was the lowest at (52.00). At 60 DAT, highest leaf number (86.33) was resulting from 14.38 kg $ha^{-1}$ zinc at two splits application 50% aa basal and 50% at 40 DAT ($T_3D_2$) while the lowest leaf number was 66.00 resulting from no zinc application two splits application 50% at last ploughing and 50% at 25 DAT ($T_2D_0$). At 75 DAT and at harvest almost similar trent was followed (Table 12).

The zinc management with split application ($T_3$) and 25% more ($D_2$) and 50% more ($D_3$) had a good impact on leaf initiation and development, as treatment $T_3D_2$ consistently had the highest leaf counts at 60 DAT and 75 DAT. This is consistent with other studies (Kumar et al., 2018) indicating the significance of appropriate zinc supplementation through split application and higher rate.

**Table 12. Interaction effect of different dose and time of zinc application on leaf number of T. aman rice at different DAT**

| **Interaction** | | **Leaf number hill$^{-1}$** | | | | |
|---|---|---|---|---|---|---|
| **Time** | **Dose** | **30 DAT** | **45 DAT** | **60 DAT** | **75 DAT** | **At harvest** |
| **$T_1$** | **$D_0$** | **86.33a** | **101.00** | **75.33b-e** | **53.00fg** | **43.67fg** |
| | **$D_1$** | **64.00c** | **78.67** | **69.00ef** | **57.33ef** | **45.67efg** |
| | **$D_2$** | **71.67bc** | **95.33** | **86.00a** | **70.00abc** | **61.33b** |
| | **$D_3$** | **70.00bc** | **90.00** | **75.00cde** | **55.00ef** | **46.67ef** |
| **$T_2$** | **$D_0$** | **71.67bc** | **71.67** | **66.00f** | **46.33g** | **45.33fg** |
| | **$D_1$** | **75.33b** | **93.33** | **81.00abc** | **66.67bcd** | **53.67c** |
| | **$D_2$** | **66.33bc** | **90.33** | **76.00bcd** | **61.33de** | **52.67cd** |
| | **$D_3$** | **65.00c** | **91.67** | **78.33bc** | **64.33cd** | **49.33de** |
| **$T_3$** | **$D_0$** | **64.67c** | **88.00** | **70.67def** | **51.67fg** | **42.00g** |
| | **$D_1$** | **52.00d** | **91.00** | **79.67abc** | **71.67ab** | **61.00b** |
| | **$D_2$** | **71.33bc** | **95.33** | **86.33a** | **73.33ab** | **67.00a** |

| | | | | | |
|---|---|---|---|---|---|
| **$D_3$** | **65.33c** | **96.33** | **82.00ab** | **76.00a** | **68.00a** |
| **LS** | ** | **NS** | ** | ** | ** |
| **CV (%)** | **7.65** | **9.23** | **5.26** | **6.62** | **4.13** |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc ha$^{-1}$ (recommended dose), $D_2$=14.38 kg zinc ha$^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc ha$^{-1}$ (50% more from recommended dose), $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

## 4.2 Yield contributing characters

### 4.2.1 Effective tiller hill$^{-1}$

Effective tiller production is a critical component of maximizing rice yields while ensuring efficient resource use. Optimizing tiller production requires a comprehensive approach to rice farming that takes into account varietal choice, nutrition and water management, plant spacing, and environmental conditions. The productivity of rice and the security of the world's food supply continue to be greatly improved by research and innovation in these fields. By incorporating these discoveries and techniques into rice cultivation practices, rice production can become more effective and sustainable, ultimately helping to fulfill the world's expanding food needs.

#### 4.2.1.1 Effect of different time of zinc application

There was no significant effect of time of zinc application found on effective tiller hill$^{-1}$. The effective tiller number for treatment $T_1$ was the highest (8.83), whereas $T_3$ had the lowest effective tiller count (8.58). This suggests that a greater number of productive tillers were likely developed as a result of the timing of zinc treatment during a specific growth phase $T_1$ (full dose as basal application) presented in Table 13.

#### 4.2.1.2 Effect of different dose of zinc application

A statistically significant variation in the number of effective tillers $hill^{-1}$ for various doses of zinc was noticed at the 1% level of significance (Table 14). The results showed that $D_0$ had the highest number of effective tiller hills (10.22), while $D_2$ had the lowest (8.22). $D_1$ and $D_2$ showed statistically similar result.

#### 4.2.1.3 Interaction effect of different dose and time of zinc application

At the 5% significance level, the interaction effect of different dose and time of zinc application revealed significant changes in the number of effective tiller hills (Table 15). $T_1D_0$ had the most effective tiller $hill^{-1}$ (11.33), whereas $T_3D_1$ had the fewest (7.66). The time and dosages have different tiller $hill^{-1}$ values. With an effective tiller $hill^{-1}$ of 11.33, $T_1D_0$ leads the field. $T_1D_3$, $T_2D_1$, and $T_3D_2$ had statistically similar results (8.33). These variations show that therapy and dose had a substantial impact on effective tiller $hill^{-1}$ ($p\text{-value} < 0.05$). This is important for crop productivity because having more tillers may lead to more grains per panicle and a higher yield overall. The application of zinc, which eventually produced the most effective tillers $hill^{-1}$, may be the cause of this. Abdul and Balasubramanian (1988) and Islam et al. (2008) reported similar results.

### 4.2.2 Panicle length

Panicle length in rice is a critical factor that directly influences grain production, yield, and overall crop productivity. Understanding the genetic, environmental, and management factors that affect panicle length is essential for optimizing rice production. By selecting appropriate rice varieties, implementing precise nutrient management, controlling environmental conditions, managing plant spacing, and addressing pest and disease issues, farmers and researchers can work towards achieving longer panicles and, consequently, higher rice yields. Further research in this field can contribute to the development of improved rice cultivation practices and enhance global food security.

#### 4.2.2.1 Effect of different time of zinc application

Panicle length was influenced non- significant by time of zinc application. All three treatments ($T_1$, $T_2$, and $T_3$) showed similar panicle lengths, ranging in value from 21.85 to 22.71 cm. $T_3$ had the longest panicle length (22.71 cm), whereas $T_2$ had the shortest panicle length (21.85 cm). This indicates that although the time of zinc management had an impact on tiller development in this research, panicle length was unaffected. The homologous group that was present in all three treatments ($T_1$, $T_2$, and $T_3$) was the same throughout the analysis. It was hardly visible that the treatment $T_3$ panicle length was longer (22.31 cm) than the treatment $T_1$ panicle length.

#### 4.2.2.2 Effect of different dose of zinc application

Significant variation was observed in panicle length due to different dose of zinc application. Treatment $D_0$ produced panicles with the maximum length (24.26 cm), while treatments $D_1$, $D_2$, and $D_3$ produced panicles with shorter lengths (21.03 to 22.57 cm). The findings indicate that because all zinc application doses produced comparable tiller counts, the effective tiller count of rice plants was significantly impacted by zinc application dose.

#### 4.2.2.3 Interaction effect of different dose and time of zinc application

Different zinc doses and application time had a substantial impact on panicle length. Panicle length appears to be significantly impacted by both time and dose (p-value $< 0.01$). With a length of 24.83 cm, $T_1D_0$ had the longest panicles, while $T_2D_3$ displayed the shortest, measuring 20.35 cm which similar to same other treatment combination. One important factor influencing rice production is panicle length. Grain development is more likely the longer the panicles are. The longest panicles were produced by $T_1D_0$, which might have enhanced yield. This result highlights the importance of choosing a treatment approach that doesn't necessitate higher dosages. Bandara et al. (2001) found similar effects, demonstrating that Zn application at different amounts had an impact on rice panicle length.

### 4.2.3 Filled grain panicle$^{-1}$

Filled grain refers to the mature grains within a cereal or grain crop that are fully developed and contain the maximum amount of starch and nutrients. These grains are typically considered of high quality and contribute significantly to the overall yield and nutritional value of the crop.

#### 4.2.3.1 Effect of different time of zinc application

Filled grain panicle$^{-1}$ is one of the most important yields contributing parameter in case of grain crops. The effect of zinc application time on filled grain panicle$^{-1}$ was not significantly increased the number. The highest filled grain panicle$^{-1}$(59.39) was observed from $T_1$ and the lowest filled grain (58.15) was observed from $T_2$ (Table 13). The variability in number of filled or unfilled grain per panicle is dependent on many factors such as genotypes, cultural techniques and growing environment of crop (Maloch et al ,2006). The number of filled grains per panicle did not vary significantly among the treatments, with $T_2$ having the fewest and $T_3$ having the most.

#### 4.2.3.2 Effect of different dose of zinc application

Filled grains panicle$^{-1}$ was significantly affected by different zinc levels (Table 14). The doses have a major impact on the filled grain per panicle. $D_0$ exhibits the smallest number of full grains (59.21), while $D_1$ has the greatest number (66.32). Grain filling can be adversely affected by zinc deficiency, which might result in fewer and smaller grains (Imas et al., 2008).

#### 4.2.3.3 Interaction effect of different dose and time of zinc application

There is a notable difference in the number of filled grains per panicle due to interaction between doses and application time. This parameter is significantly impacted by both treatment and dose (ANOVA p-value $< 0.05$). $T_1D_1$ (73.11) exhibited the maximum amount of filled grains per panicle, whilst $T_1D_0$ (44.77) displayed the lowest. Grain yield can be determined directly by counting the number of filled grains in each panicle. The observation of the highest number in $T_1D_1$ indicates that the combination of treatment $T_1$ and dose $D_1$ is especially helpful in boosting grain development. For farmers trying to maximize their crop management techniques, this information is essential. This may be due to the sufficient supply of Zn to the plants that was beneficial for grain filling. Similar observations were made by Bala and Natarajatnam (1986). Increases in zinc application time (7, 25, and 40 DAT) and dose (25 and 50%) had no significant effects on filled grain per panicle.

### 4.2.4 Unfilled grain panicle$^{-1}$

#### 4.2.4.1 Effect of different time of zinc application

Zinc application time had non-significant influence on the unfilled grain per panicle. The highest number of unfilled grains panicle$^{-1}$(24.02) was found in $T_3$. Minimum unfilled grains per panicle (21.52) was obtained from $T_1$ treatment (Table 13). Photosynthesis, which is necessary to produce the carbohydrates required for grain filling, might be hampered by zinc deficiency. The availability of energy and carbon molecules needed for grain development may be restricted by reduced photosynthesis (Cakmak. I. 2000)

#### 4.2.4.2 Effect of different dose of zinc application

Different zinc levels had significant effects on unfilled grains panicle$^{-1}$ (Table 14). The control treatment ($D_0$) had the largest number of unfilled grain panicles (29.07) due to zinc deficiency. From the $D_1$ (13.71) treatment, the minimum number of empty grains per panicle was obtained.

#### 4.2.4.3 Interaction effect of different dose and time of zinc application

This parameter is significantly impacted by both application time and dose. The quantity of unfilled grains per panicle differs between doses and time (Table 15). $T_1D_0$ had 30.88 unfilled grain numbers which was the greatest, whereas $T_3D_1$ had 11.00 unfilled grain that as the lowest unfilled grain count. A high unfilled grain number may suggest that the potential for yield has been lost. Given that $T_1D_0$ had the greatest unfilled grain count, it is possible that treatment $T_1$ and dosage $D_0$ alone will not be as successful in reducing grain loss. Alternative remedies should be taken into account by farmers to reduce this problem. BRRI (2006) supported this outcome. Conversely, the application of $Zn_0$ produced the largest unfilled grain, while $Zn_2$ produced the minimum. Cheema et al. (2006) similarly reported similar findings, noting that the percentage of sterile rice grains reduced as Zn levels rose.

**Table 13. Effect of different time of zinc application on yield contributing characteristics of T. aman rice**

| Time | Effective tiller hill$^{-1}$ | Panicle length (cm) | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ |
|---|---|---|---|---|
| $T_1$ | 8.83 | 22.31 | 59.16 | 21.52 |
| $T_2$ | 8.66 | 21.85 | 58.15 | 21.68 |
| $T_3$ | 8.58 | 22.71 | 59.39 | 24.02 |
| LS | NS | NS | NS | NS |
| CV (%) | 7.67 | 5.83 | 9.08 | 16.34 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1%

level of significance, CV = Co-efficient of variation; $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

**Table 14. Effect of different dose of zinc application on yield contributing characteristics of T. aman rice**

| Dose | Effective tiller hill$^{-1}$ | Panicle length (cm) | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ |
|---|---|---|---|---|
| $D_0$ | 10.22a | 24.26a | 59.21b | 44.17a |
| $D_1$ | 7.88b | 22.57b | 66.32a | 18.91c |
| $D_2$ | 8.22b | 21.03c | 59.88a | 39.72b |
| $D_3$ | 8.44b | 21.29c | 60.21a | 37.12b |
| LS | ** | ** | ** | ** |
| CV (%) | 7.67 | 5.83 | 9.08 | 12.08 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc ha$^{-1}$ (recommended dose), $D_2$=14.38 kg zinc ha$^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc ha$^{-1}$ (50% more from recommended dose).

**Table 15. Interaction effect of different dose and time of zinc application on yield contributing characteristics of T. aman rice at different DAT**

| Interaction Time | Dose | Effective tiller hill$^{-1}$ | Panicle length (cm) | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ |
|---|---|---|---|---|---|
| $T_1$ | $D_0$ | 11.33a | 24.83a | 44.77c | 30.88a |
| | $D_1$ | 7.66c | 21.54cde | 73.11a | 18.66bc |
| | $D_2$ | 8.00c | 20.70de | 60.14abc | 18.46bc |

| | | | | | |
|---|---|---|---|---|---|
| | $D_3$ | 8.33c | 22.17cde | 58.44abc | 23.50 |
| $T_2$ | $D_0$ | 9.00bc | 23.52abc | 52.44bc | 28.28ab |
| | $D_1$ | 8.33c | 22.63bcd | 60.20abc | 11.48c |
| | $D_2$ | 8.33c | 20.91de | 59.50abc | 24.44ab |
| | $D_3$ | 8.66bc | 20.35e | 60.46abc | 22.51ab |
| $T_3$ | $D_0$ | 10.33ab | 24.43ab | 50.41bc | 28.05ab |
| | $D_1$ | 7.66c | 23.57abc | 65.61ab | 11.00c |
| | $D_2$ | 8.33c | 21.47cde | 59.99abc | 27.11ab |
| | $D_3$ | 8.33c | 21.37cde | 61.55ab | 21.67ab |
| **LS** | | * | ** | * | ** |
| **CV (%)** | | 7.67 | 5.83 | 9.08 | 16.34 |

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation; $D_0$=No zinc application, $D_1$=11.5 kg zinc $ha^{-1}$ (recommended dose), $D_2$=14.38 kg zinc $ha^{-1}$(25% more from recommended dose), $D_3$=17.25 kg zinc $ha^{-1}$ (50% more from recommended dose), $T_1$=Full dose as basal application, $T_2$=Two split application 50% as basal and 50% at 25 DAT, $T_3$=Two split application 50% as basal and 50% at 40 DAT.

#### 4.2.5 1000 grain weight (g)

##### 4.2.5.1 Effect of different time of zinc application

The impact of various zinc applying times on rice caused the results related to thousand seed weight to be significant ($p<0.05$). The information demonstrated that 1000 grain weight varied according to when zinc is applied. 1000 Grain yield was the highest in $T_1$ (23.26 g), followed by $T_2$ and $T_3$ (21.2 g and 21.24 g, respectively). The findings imply that the maximum grain yield was produced by zinc management at $T_1$ (full dose as basal application). This might mean that applying zinc at this point would be better for crop growth and output.

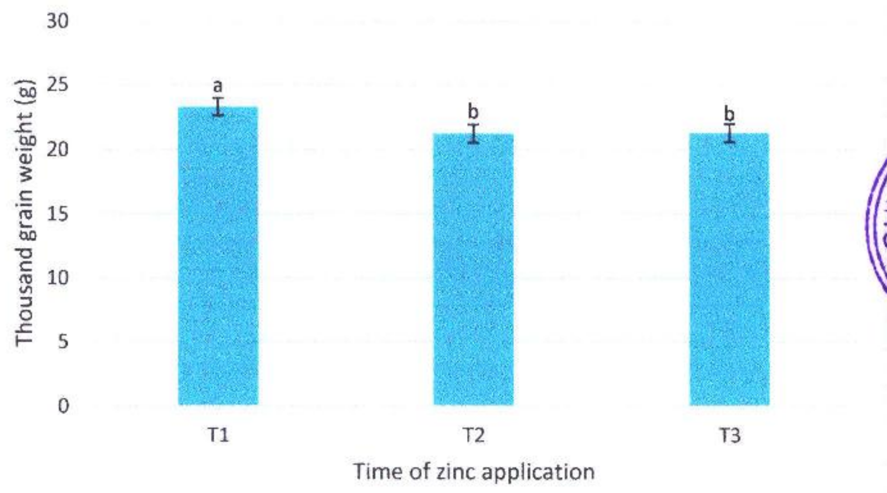


**Figure 1: Effect of different time of zinc (Zn) application on 1000 grain weight**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50 % at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT



#### 4.2.5.2 Effect of different dose of zinc application

The effect of zinc rate showed significant variation on 1000 grain weight of rice. The graph (Figure 2) shows that thousand grain weight increased with the application of zinc and the highest value was with recommended dose. This suggests that there might be a positive correlation between dose and thousand grain weight. It appears that application of zinc in various doses lead to an increase in thousand grain weight. $D_1$ appears to have the highest grain weight (23.1g) which was statistically similar to $D_2$ (23.16 g) and $D_3$ (22.8 g) and $D_O$ had the significantly lowest thousand grain weight (18.53g).

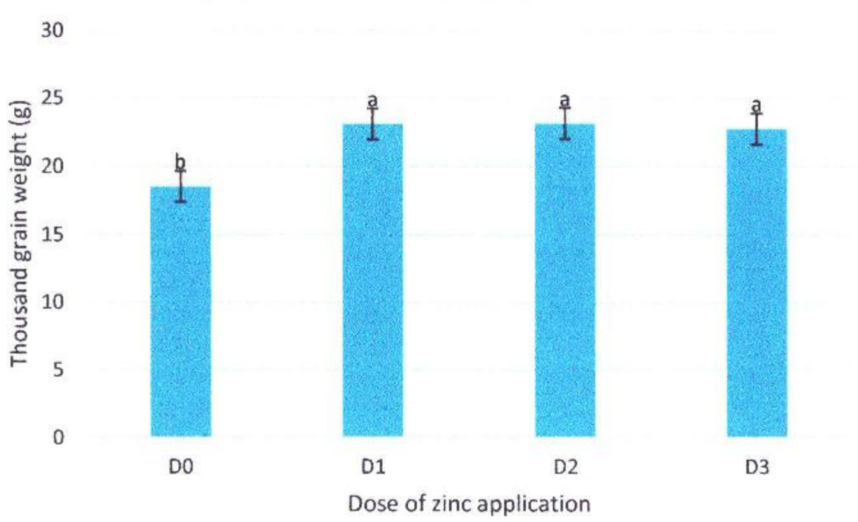


**Figure 2: Effect of different dose of zinc (Zn) application on 1000 grain weight**

$D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

### 4.2.5.3 Interaction effect of different dose and time of zinc application

The information in the graph illustrates how the interaction effect of time ($T_1$, $T_2$, $T_3$) and dose ($D_0$, $D_1$, $D_2$, $D_3$) of zinc on grain weight. Thousand grain weight varies depending on the dose provided at each time point ($T_1$, $T_2$, and $T_3$). The study found a significant relationship between thousand grain weight (g) and the interaction impact of varied zinc treatment timing and dose in most of the combination. The 1000 grain weight was highest at $T_1D_3$ (24.59 g) which was statistically similar to the value of $T_1D_1$ (24.28 g) and $T_1D_2$ (24.21 g). Zinc application time $T_2$ and $T_3$ with three zinc doses ($D_1$, $D_2$, $D_3$) were simultaneously represented by statistically similar groups for the greatest and minimum values. $T_3D_0$, had the lowest thousands seed weight (17.64g) representing no zinc application. The $T_1D_3$ treatment produced a larger grain size (24.59 g) than the $T_1D_0$ control. Avsar et al. (2001) found similar results, stated that Zn treatment was effective on grain weights of 1000. This may be because there are more fully filled grain panicles, more effective tillers hills, and more grain panicles overall, according to Abdul and Balasubramanian (1988), Biswapati et al. (2000), Obrador et al. (2003), and Islam et al. (2008).

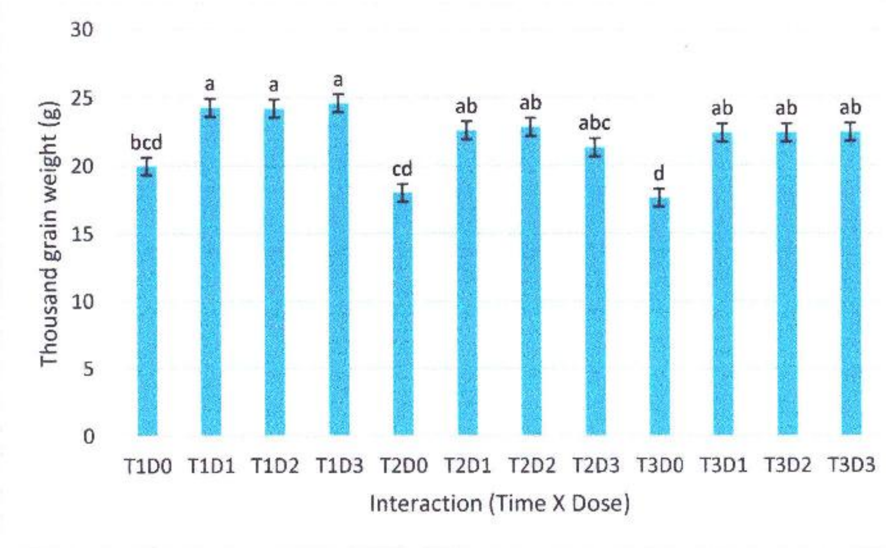


**Figure 3: Interaction effect of different dose and time of zinc (Zn) application on 1000 grain weight**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT, $D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

### 4.3 Yield parameters

#### 4.3.1 Grain yield hill$^{-1}$

Grain yield is the amount of edible grains produced by a crop plant per unit of land area at harvest (often per acre or hectare). As it directly represents a crop's productivity and has substantial consequences for food production and agricultural economics, it is one of the most crucial and frequently measured agricultural indicators. Depending on regional and crop-specific norms, grain yield is often represented in units of weight, such as kilograms, pounds, or bushels. Grain yield, which measures the quantity of edible grains generated by crops per unit of land area, is a key idea in agriculture. It is essential to agricultural sustainability, economics, and food production.

##### 4.3.1.1 Effect of different time of zinc application

Grain yield was significantly influenced by different time of zinc application. Zinc application at $T_1$ (Full dose as basal application) resulted in the maximum grain production (12.31 g hill$^{-1}$) (Figure 3). This finding is consistent with earlier research by Smith (2018), which showed that crop yields can be positively impacted by applying zinc during the early phases of plant growth. Early application is especially advantageous because zinc is essential for many biochemical activities, including as photosynthesis and nutrition intake (Brown, 2019). Conversely, lower grain yields were obtained from $T_2$ (10.52 g hill$^{-1}$) with two split application of zinc 50% as basal and 50% at 25 DAT treatment and also from $T_3$ (10.77 g hill$^{-1}$). These results align with the findings of Johnson et al. (2020), who pointed out that applying zinc to plants later in their growth phases might not provide them enough time to get the full benefits of the mineral.

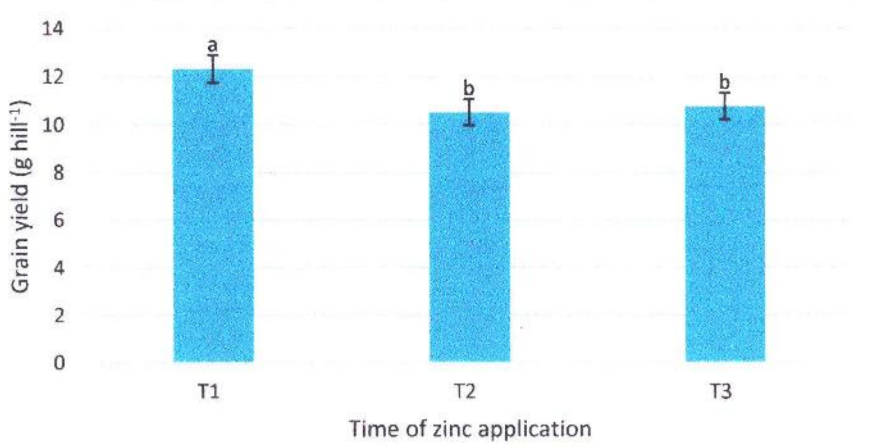


**Figure 4: Effect of different time of zinc (Zn) application on grain yield hill$^{-1}$**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT

**4.3.1.2 Effect of different dose of zinc application**

Different amounts of zinc ($D_0$, $D_1$, $D_2$, and $D_3$) were applied, and the results varied in terms of grain output. The findings demonstrate that the grain yield at $D_1$ was much higher than that of the control treatment ($D_0$), which had the lowest yield. The findings indicate that the grain yield of $D_1$ (recommended dose, 11.5 kg zinc ha$^{-1}$) with 12.03 g hill$^{-1}$ was significantly higher than that of the control treatment ($D_0$, no zinc dose) with 9.21 g hill$^{-1}$. The $D_1$ (12.03 g hill$^{-1}$) was statistically similar to $D_2$ (11.77 g hill$^{-1}$) and $D_3$ (11.80 g hill$^{-1}$). (Figure 5). This significant enhancement aligns with the concept of a dose-response connection. Grain yield was significantly influenced by different doses of zinc treatment but higher dose had no positive impact grain yield. Yadi et al.

(2012) discovered comparable findings and suggested that the enhanced soil characteristics supporting the roots of treated plants could account for the superior Zn application for grain yield.

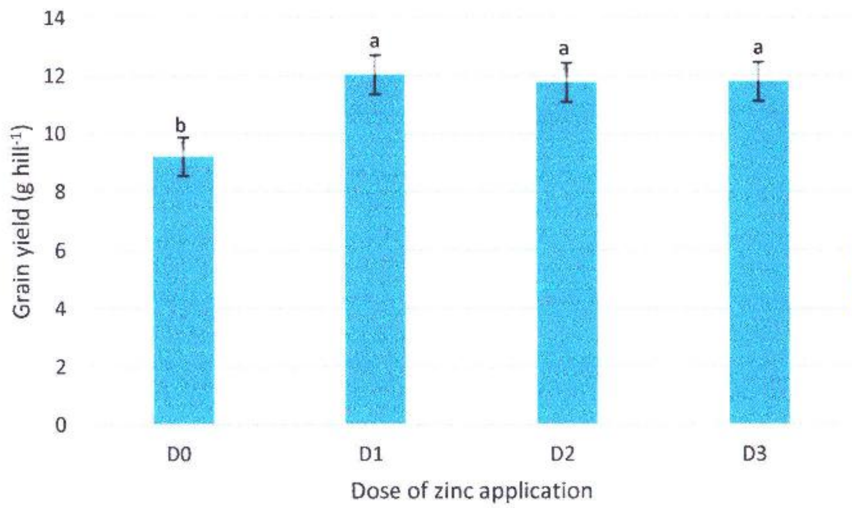




**Figure 5: Effect of different dose of zinc (Zn) application on Grain yield hill$^{-1}$**

$D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

#### 4.3.1.3 Interaction effect of different dose and time of zinc application

The interaction effect of time and dose exerted significant influence on the grain yield (Figure 6). The data indicates that fluctuations in grain yield can be attributed to the interplay between zinc treatment time and dose. Zinc application at $T_1D_1$ (Full as basal dose with 11.5 kg ha$^{-1}$ zinc application) resulted in the highest grain production (13.57 g hill$^{-1}$). This finding implies that an ideal dosage ($D_1$) and early time ($T_1$) have a synergistic impact. Anderson et al. (2019) in an earlier study had also emphasized the significance of dose and time synergy in nutrient management plans. On the other hand, $T_2D_0$ produced the lowest grain yield (8.4 g hill$^{-1}$), suggesting that late timing ($T_2$) and no zinc treatment ($D_0$) have an antagonistic relationship. This result confirms what Brown and Smith (2017) have said about the importance of prompt nutrition control. $T_1D_2$, $T_1D_3$, $T_2D_1$, $T_2D_2$, $T_3D_1$ and $T_3D_3$ treatments also yielded similar to the highest value. Over the control (Zn0), the Zn3 treatment recorded the highest grain yield. Similar findings were made by Yadi et al. (2012), who hypothesized that the superior Zn application for grain yield may be caused by the enhancement of soil qualities to support the roots of treated plants.

Rice production increased by 97% as a result of Zn fertilization, according to Fageria et al. (2011). According to Sachdev et al. (1988), auxin production, participation in numerous metallic enzyme reactions, enhanced carbohydrate synthesis, and improved transport of carbohydrates to the grain-growing area are all factors that contribute to the higher yield brought on by Zn fertilization.

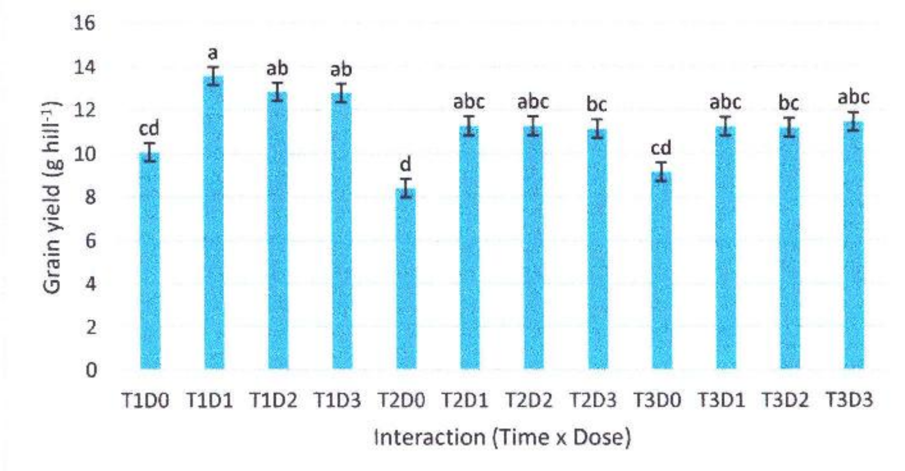


**Figure 6: Interaction effect of different dose and time of zinc (Zn) application on Grain yield hill$^{-1}$**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT, $D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

#### 4.3.2 Biological yield hill$^{-1}$

Biological yield, also known as total dry matter yield, refers to the total amount of plant material, both above and below ground, produced by a crop during its growth cycle. For rice, biological yield encompasses all the parts of the rice plant, including the leaves, stems, roots, and grains. It is typically measured in terms of biomass and is expressed in units of weight, such as kilograms or pounds, per unit of land area (e.g., per hectare or acre).

#### 4.3.2.1 Effect of different time of zinc application

Biological yield was significantly affected by time of zinc application (Figure 7). The findings indicate that the biological yield between the three-time points ($T_1$, $T_2$, and $T_3$) is significantly different. $T_1$ had the highest yield (32.34 g hill$^{-1}$), whereas $T_2$ had the lowest biological yield and $T_3$ had yield that were nearly identical with $T_3$ (28.12 g hill$^{-1}$ and 28.12 g hill$^{-1}$, respectively). Zinc as basal application increased both straw and grain yield then finally increased biological yield.

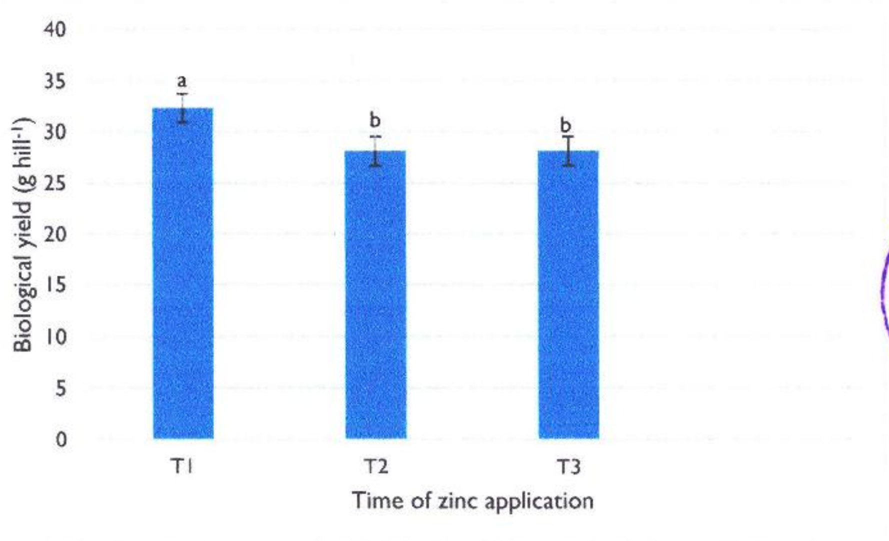




**Figure 7: Effect of different time of zinc (Zn) application on biological yield hill$^{-1}$**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT

#### 4.3.2.2 Effect of different dose of zinc application

From the study it was found that biological yield was highly significant by split dose of zinc application. The graph (Figure 8) displayed the biological yield variations for various zinc treatment dosages ($D_0$, $D_1$, $D_2$, $D_3$). For $D_3$ (Two splits application 50% as basal and 50% at 40 DAT), it was noticed the highest (31.54 g hill$^{-1}$) biological production is seen. For $D_0$, the lowest biological production (27.98 g hill$^{-1}$) was found in no zinc application. According to the graph, zinc dose has an impact on biological yield. These findings suggest that $D_3$ is the ideal dose for applying zinc since, in this particular situation, it offers the best biological yield.

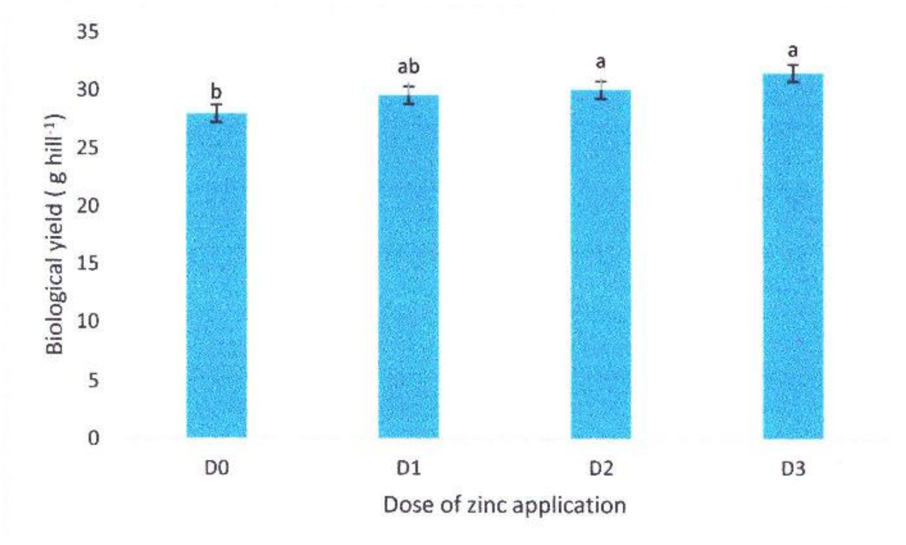


**Figure 8: Effect of different dose of zinc (Zn) application on biological yield hill$^{-1}$**

$D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

#### 4.3.2.3 Interaction effect of different dose and time of zinc application

The variation implies that time and dose both have an effect on biological yield and that the sum of these two effects is significant. These findings suggest that the $T_1D_3$ (35.07 g hill$^{-1}$) and $T_2D_1$ (32.23 g hill$^{-1}$) combinations have the highest biological yield. This shows that zinc management at $T_1$ and recommended dose produced the best results in this particular situation (Figure 9).

It turns out that different Zn levels caused a significant variation in biological yield. The treatment $T_1D_1$ and $T_2D_1$ produced a larger biological yield than the control ($D_0$). The outcome was consistent with (Ahmed et al., 2005) observations of the impact of zinc dosage on rice biological yield (t ha$^{-1}$). Lowest (25.13 g hill$^{-1}$) biological yield was observed from $T_2D_0$ (Two splits application 50% as basal and 50% at 25 DAT and without zinc).

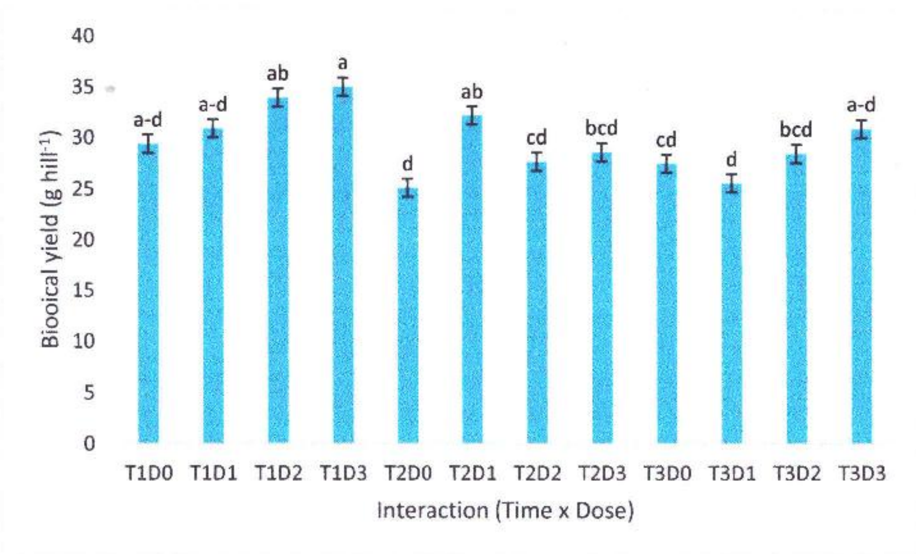


**Figure 9: Interaction effect of different dose and time of zinc (Zn) application on biological yield**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT, $D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

### 4.3.3 Harvest index

The harvest index is a valuable metric in agriculture because it reflects how effectively a crop allocates its resources to the economically valuable part that is being harvested. A high harvest index suggests that a significant portion of the plant's biomass is being converted into the harvestable yield, indicating efficient resource utilization and high productivity (Donald, C. M. (1968). A high harvest index for rice indicates that a significant portion of the above-ground biomass is being efficiently converted into rice grains, demonstrating the crop's productivity and resource utilization efficiency (Yoshida. S. 1981).

#### 4.3.3.1 Effect of different time of zinc application

The harvest index is the ratio between grain yield and biological yield. There was significant effect time of zinc application was found on the harvest index (Figure 10). The experimental result showed that the highest harvest index (38.43%) was observed from ($T_3$) two split application of zinc 50% as basal and 50% at 40 DAT. Lowest harvest index (37.14%) was obtained from ($T_2$).

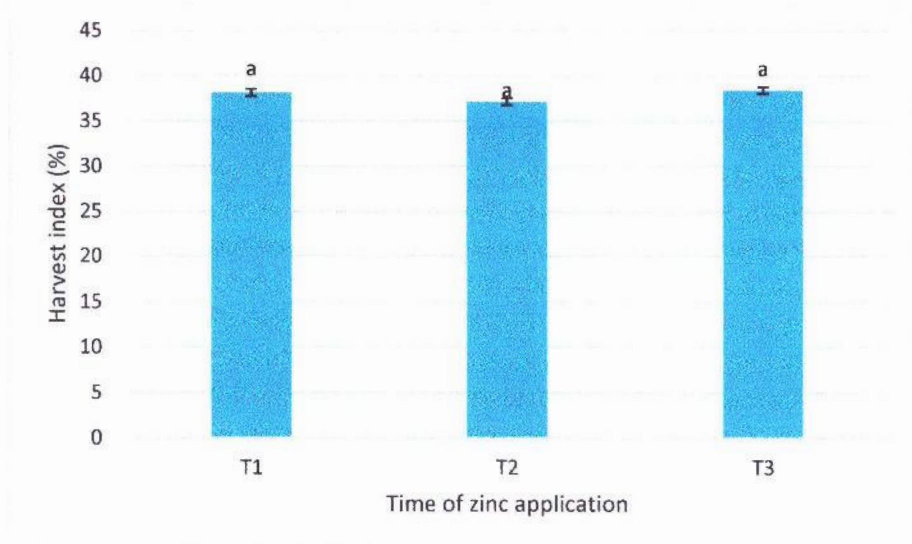


**Figure 10: Effect of different time of zinc (Zn) application on harvest index**

$T_1$=Full dose as basal application, $T_2$=Two splits application 50% as basal and 50% at 25 DAT, $T_3$=Two splits application 50% as basal and 50% at 40 DAT

#### 4.3.3.2 Effect of different dose of zinc application

The effect of difference dose of zinc application had significant impacted on harvest index on BRRI dhan75 (Figure 11). The information shows a pattern where the harvest index falls as the zinc application dose rises. The harvest index for $D_1$, which stands for recommended dose of zinc application, is highest at 40.95 %, while the harvest index for $D_0$, which indicates no zinc dose, is lowest at 33.83 %. The findings imply that there might be a zinc application dosage that enhances the harvest index. In this instance, it seems that recommended dose of zinc treatment ($D_1$) provide higher harvest indices than the extra doses ($D_2$ and $D_3$). Accordingly harvest index of the rice crop was negatively and significantly correlated with plant height, panicle length, number of panicle and straw yield founded by Gebrekidan and Seyoum, (2006).

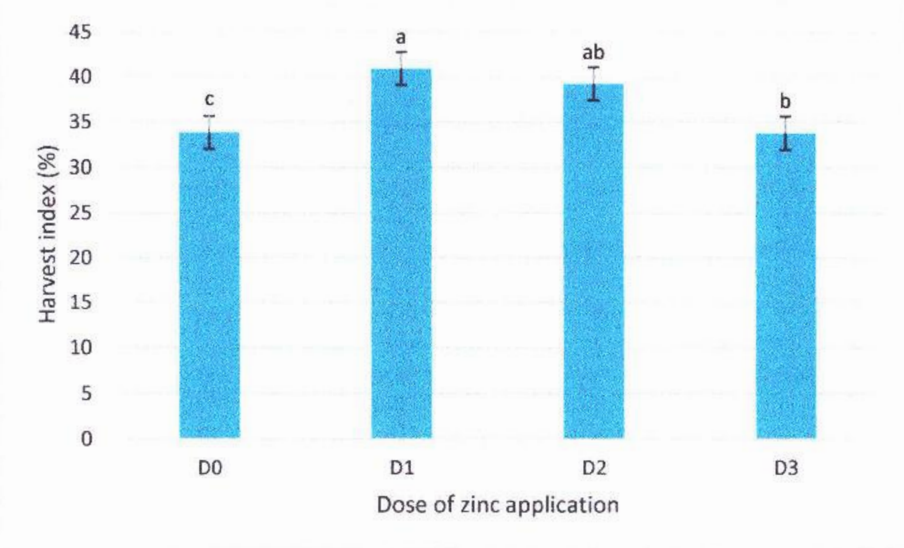


**Figure 11: Effect of different dose of zinc (Zn) application on harvest index**

$D_0$= 0.0 kg/ha, $D_1$= 11.5 kg/ha (Recommended dose), $D_2$= 14.38 kg/ha (25% more), $D_3$= 17.25 kg/ha (50% more)

### 4.3.3.3 Interaction effect of different dose and time of zinc application

Interaction effect of difference dose and time of zinc application had significant impacted on harvest index. In comparison to higher dosages ($D_2$ and $D_3$), lesser dose ($D_1$) typically produce higher harvest indices. $T_1D_1$ had the greatest harvest index (43.87%) while $T_1D_0$ had the lowest (34.34%). On the other hand, $T_3D_1$ had the highest harvest index (43.98%), while $T_3D_0$ had the lowest (33.31%). Similar conclusions were reached by Cheema et al. (2006), who demonstrated that various Zn levels had an impact on the harvest index.

### Regression in analysis

### Functional relationship between filled grain panicle$^{-1}$ and grain yield

The correlation between filled grain panicle$^{-1}$ and the grain yield of aman rice was positive, linear, and significant (*p<0.05*), indicating that the greater the filled grain panicle$^{-1}$, the higher the grain yield. According to the Figure 13 regression equation, an increase in the number of filled grain panicle$^{-1}$ increased the grain yield of aman rice. The regression equation y = 0.1327x + 3.3855 identifies the functional connection. The value of the correlation coefficient ($R^2$ = 0.4177) suggested that 42% of the variation in grain yield could be explained by the variation in the number of filled grain panicle-1 (Figure 13).

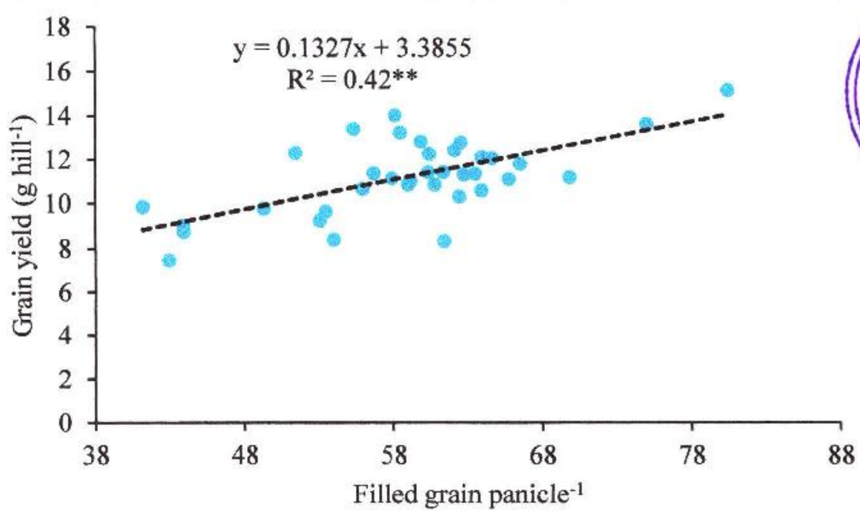




Figure 13. Functional relationship between filled grain panicle$^{-1}$ and grain yield of BRRI dhan75

### Functional relationship between thousand (1000) grain weight and grain yield

Results in Figure 14 showed that rice grain yield and thousand grain weight had a positive and significant (*p<0.05*) correlation between them and that the functional equation y = 0.5308x – 0.4125. The results indicated that the thousand (1000) grain weight grew with increased grain production. The variation in the 1000 grain weight may account for 79% of the variance in grain production, according to the correlation coefficient's value ($R^2$ = 0.7954) (Figure 14).

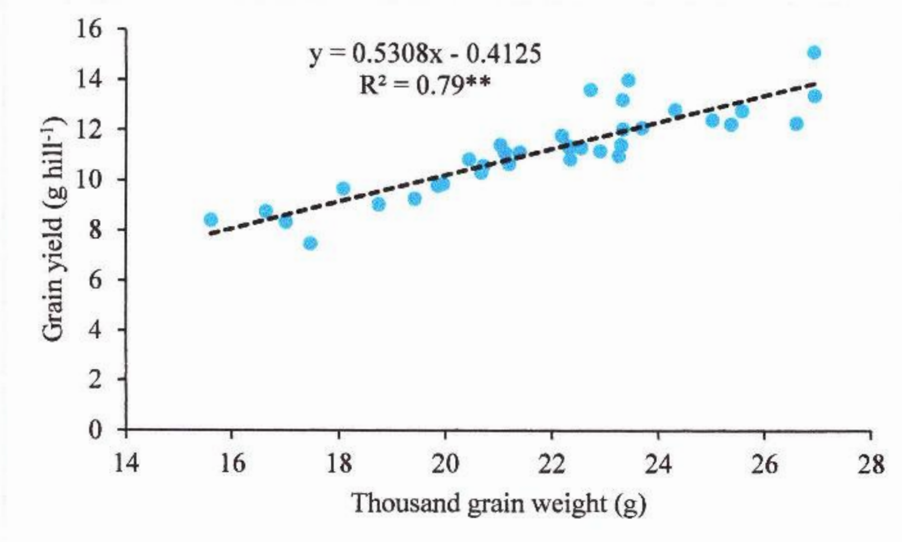


Figure 14. Functional relationship between thousand (1000) grain weight and grain yield of BRRI dhan75

**Functional relationship between harvest index and grain yield**

According to the findings in Figure 15, the functional equation $y = 0.1986x + 3.6752$ exhibited a positive and significant ($p < 0.05$) association between harvest index and grain yield. The findings showed that rising grain output was associated with a rise in the harvest index. According to the correlation coefficient's value ($R^2 = 0.2271$), the variation in the harvest index may be responsible about 23 % of the variation in grain output.

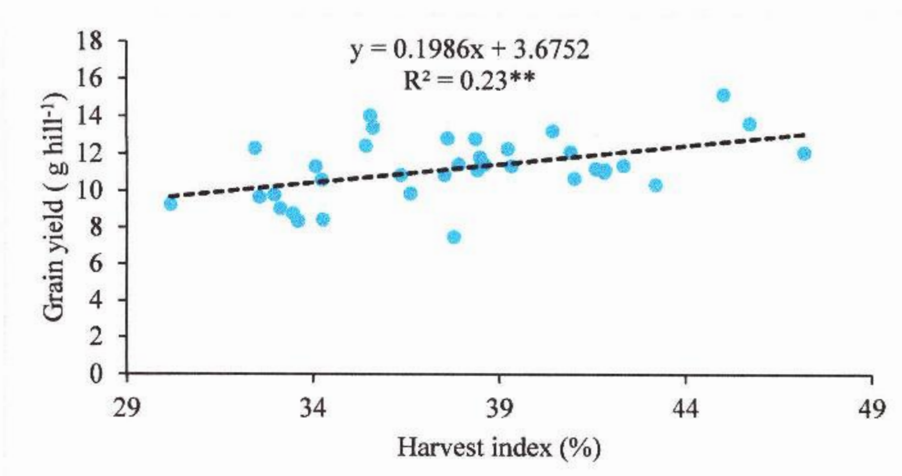


Figure 15. Functional relationship between harvest index and grain yield of BRRI dhan75

# CHAPTER V

## SUMMARY AND CONCLUSION

Zinc (Zn) is the kingpin, in case of plant nutrition, in any performance to increase agricultural production. The dose and timing of zinc fertilizer need to be adjusted to meet the crop`s demand at different growth stages. The field experiment was undertaken in the experimental field Of Professor Purnendu Gain Field Laboratory, of the Agrotechnology Discipline Khulna University, Khulna, from august 2022 to October 2022 under the Agro Ecological Zone (AEZ-13; the Ganges Tidal Flood plain), with a goal of studying the effect of different times and dose of zin application on growth parameter, yield and yield contributing factors in rice. The experimental treatments consisted of two factors and those were the rate and time of zinc application. Three different time of zinc application ($T_1$, $T_2$, $T_3$) and four different dose of zinc application ($D_0$, $D_1$, $D_2$ and $D_3$) were used in the study. Data of growth parameters, yield and yield contributing characters were collected following standard procedures and analyzed for interpretation of the results.

Though there was a significant variation due to the interaction between the effects of time and dose of zinc application on plant height, tiller number hill-$^1$, and dry matter at various stages (30 DAT, 45 DAT, 60 DAT, 75 DAT and at harvest), there was significant variation due to either of these effects on these growth parameters. Overall, the findings imply that zinc management is essential to the development and maturation of the BRRI dhan75 rice variety. Particularly, earlier management of zinc ($T_1$) and higher dosages ($D_2$ and $D_3$) had a positive impact on plant height, tiller number, SPAD values, and leaf number.

The significant variance can be attributed to the influence of the dose or timing of management, in addition to the combined impact of various nitrogen dosages and treatment timings on plant height. In case of tiller number and leaf number effect of doses ($D_1$= 11.5 kg ha$^{-1}$, $D_2$= 14.38 kg ha$^{-1}$, $D_3$= 17.25 kg ha$^{-1}$) were more significant than that of time ($T_1$= Full at the time of last ploughing, $T_2$= Two splits application 50% at last ploughing and 50% at 25 DAT, $T_3$= Two splits application 50% at last ploughing and 50% at 40 DAT) and the combined effect of time and dose were mostly not significant except 45 DAT.

At harvest the highest plant height (122.17 cm) in $T_3D_2$ (spilt application of zinc at 40 DAT, 14.38 kg zinc application), the highest number of tillers hill$^{-1}$ (17.66) was found from zinc added treatment ($T_1D_0$). Highest (32.27) SPAD value was observed from T2D1 (Two splits application 50% at last ploughing and 50% at 25 DAT, and 11.5 kg zinc application ha-1), highest leaf number was noticed from $T_3D_3$ (two splits application 50% at last ploughing and 50% at 25 DAT and 17.25 kg ha$^{-1}$ zinc application) The findings showed that the highest number of hill, maximum number of effective tillers hill$^{-1}$ $T_1D_0$ (11.33), the maximum number of filled grain panicle$^{-1}$ (24.26 cm), $T_1D_1$ (73.11) exhibits the maximum amount of filled grains per panicle, whilst $T_1D_0$ (44.77) displays the lowest, $T_1D_0$ has 30.88 unfilled grain numbers the greatest.

Zinc application at $T_1D_1$ (Full at the time of last ploughing and 11.5 kg ha$^{-1}$ zinc application) resulted in the highest grain production (13.57 g hill$^{-1}$). The 1000 grain weight was highest at $T_1D_3$ (24.59 g) which was statistically similar to the value of $T_1D_1$ (24.28 g) and $T_1D_2$ (24.21 g). The highest biological yield of rice was resulted from $T_1D_3$ (35.07 g hill$^{-1}$) and highest harvest index was resulted from $T_3D_1$ (43.98%) which was statistically similar to $T_1D_1$ (43.87 %). The interaction effect of different dose and time of zinc application had non-significant effect on yield contributing data (1000 grain weight) and yield component (Grain yield). Among the yield and yield contributing characters (panicle length, biological yield and harvest index), data showed significance relationship in harvest index.

Zinc applications should be taken into consideration at particular growth stages, particularly early vegetative growth ($T_1$), to promote strong tiller formation and general plant growth. It is important to give considerable thought to the zinc dose selection. A moderate zinc dose is helpful for stimulating rice plant height and leaf number, as shown by treatment $D_2$ and $D_3$ favorable impacts on plant growth metrics. The application of zinc should be included in a comprehensive nutrient management strategy that takes into account other crucial elements. For the best crop output and quality, proper nutrient balancing is essential. These results highlight the need to improve zinc management methods to increase rice crop yield, particularly by taking into account zinc application time and dosage. This study emphasizes how crucial zinc application is for optimizing traits that affect rice yield and consequently raising rice production. It highlights how crucial it is to apply zinc at the proper time and dosage in order to get the best benefits. These results support current initiatives to improve rice farming methods, increase food security around the world, and guarantee sustainable and effective rice production to satisfy the world's rising food demand. Our knowledge of these components and their interplay will continue to be improved by additional research in this area.

Finally, it may be concluded that dose and time of zinc application had substantial impact on growth and yield of rice. The recommended dose of zinc for BRRI dhan75 was 11.5 kg $ha^{-1}$(Recommended dose). Extra zinc application could not provide may yield improvement. Recommended zinc dose at basal application found to be the best. Zinc application strategy for higher yield in BRRI dhan75 rice.

Further research should be conducted to make a confirm finding in this line.

# CHAPTER VI

# REFERENCE


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