EFFECT OF INTEGRATED WEED MANAGEMENT ON GROWTH AND YIELD OF AROMATIC RICE

A THESIS

BY

DIPIKA PAL
STUDENT ID. 1701035
SESSION: 2024-25
SEMESTER: JANUARY-JUNE 2025

MASTER OF SCIENCE (M.S.)
IN
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DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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JUNE 2025

DEDICATED

TO

MY BELOVED PARENTS

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First and first, I want to express my profound appreciation to God, the All-Knowing, All Powerful, who made it possible for me to pursue a degree in agriculture and to finish my thesis for the Master of Science (MS) in Agronomy Department.

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The author

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ABSTRACT

This study was conducted at the Agronomy field of Hajee Mohammad Danesh Science and Technology University to evaluate the effects of integrated weed management strategies (T_1 = control, T_2 = Pre-emergence herbicide + one hand weeding, T_3 = Post-emergence herbicide + one hand weeding 20 DAT and T_4 = Pre-emergence herbicide + Post-emergence herbicide 40 DAT) and two aromatic rice varieties (V_1 = Kalizira and V_2 = Tulsimala) on the growth and yield performance. A two factor RCBD design with three replications was employed for the experiment. Results revealed that, variety Tulshimala V_2 showed the longest plant height (159.30 cm at harvest), number of tillers hill^{-1} (14.49 at 90 DAT), number effective of tillers hill^{-1} (13.90), panicle length (20.22 cm), number of grains panicle^{-1} (173.90), number of filled grains panicle^{-1} (162.64), 1000-grain weight (13.17 g), grain yield (2.19 t ha^{-1}), straw yield (5.78 t ha^{-1}) and harvest index (30.94%). While highest number of non-effective tillers hill^{-1} (4.19), number of unfilled grains panicle^{-1} (19.97) and biological yield (7.97 t ha^{-1}) was seen from Kalizira variety (V_1). On the other hand, T_3 showed the longest plant height (165.93 cm at harvest), number of tillers hill^{-1} (18.67 at 90 DAT), number effective of tillers hill^{-1} (16.89), panicle length (22.61 cm), number of grains panicle^{-1} (178.14), number of filled grains panicle^{-1} (166.33), 1000-grain weight (13.41 g), yield (2.40 t ha^{-1}), biological yield (8.20 t ha^{-1}) and harvest index (29.31%). The highest number non-effective of tillers hill^{-1} (7.97), number of unfilled grains panicle^{-1} (27.36) was found from (T_1) and straw yield (5.78 t ha^{-1}) from (T_4). Interaction effect of variety and integrated weed management had also significant influenced on growth, yield and yield contributing traits of aromatic rice. Treatment V_2T_3 showed the best performance across all the growth and yield characters; longest plant (170.20 cm at harvest), number of tillers hill^{-1} (18.38 at 90 DAT), number of effective tillers hill^{-1} (18.67), panicle length (24.13 cm), number of grains panicle^{-1} (178.98), number of filled grains panicle^{-1} (173.67), 1000-grain weight (14.04 g), grain yield (2.61 t ha^{-1}), straw yield (5.85 t ha^{-1}), biological yield (8.46 t ha^{-1}) and harvest index (30.94%). These findings suggest that Tulshimala variety exhibits a significantly enhanced performance under the integrated weed management practice of post-emergence herbicide application with one hand weeding at 90 DAT, recommending its potential as an effective strategy for improving yield outcomes in the study region.

Keywords: Aromatic rice, herbicide, Tulshimala, Kalizira

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L*)*, belonging to the family Poaceae, is the cornerstone of agriculture in tropical and subtropical regions. According to the Bangladesh Bureau of Statistics (BBS, 2024), Bangladesh stands as the third largest rice-producing country globally, highlighting the crop's critical importance to the nation's economy and food security. In FY2023-24, Bangladesh's agriculture sector is estimated to have grown by 3.21%, a slight decrease from the 3.37% growth in the previous fiscal year. This sector contributed approximately 11.55% to the country's gross domestic product. Provisional data from the Bangladesh Bureau of Statistics (BBS) indicates that the overall GDP grew by 5.82% in FY2023-24. It is the most widely consumed staple food grain globally, serving as the primary source of calories for over half of the world's population. It contributes approximately 20% of the world's dietary energy supply and is particularly essential in Asia, where more than 90% of the global rice is produced and consumed (FAO, 2024). In South and Southeast Asia, rice is not merely a food item but a cultural cornerstone, intertwined with the social fabric, economic stability, and environmental management of the region (IRRI, 2021). The global demand for rice is expected to rise substantially due to increasing population pressure. With the world population projected to exceed 9.7 billion by 2035, it is estimated that rice production will need to increase by about 25-30% by 2050 to meet the growing food requirements (Timsina *et al.* 2023). However, achieving this goal is becoming increasingly difficult due to challenges like diminishing arable land, labor shortages, water scarcity, climate change, and biotic stresses including pest and weed infestations (Basu and Rao, 2020). Bangladesh ranks among the top ten rice-producing countries globally and has one of the highest per capita rice consumption rates. Rice dominates the cropping pattern, accounting for nearly 55% of the total cropped area in the country (BBS, 2024). The country cultivates rice in three major seasons: aus (pre-monsoon), aman (monsoon), and boro (dry winter season with irrigation). Among these, aman rice occupies the largest area, covering around 5.2 million hectares and producing more than 13 million metric tons of rice annually (DAE, 2024). Despite significant advances in rice production technologies, Bangladesh still faces the dual challenge of improving rice productivity and ensuring sustainability. The average yield remains relatively low compared to other rice-producing countries, primarily due to biotic and abiotic constraints including sub-optimal crop management, declining soil fertility, pest pressure, and severe weed competition (Mahmud *et al.* 2023). Aromatic rice forms a distinct group of rice varieties known for their unique fragrance, fine grain quality, and exceptional cooking characteristics. These varieties contain elevated levels of 2-acetyl-1-pyrroline (2-AP), a volatile compound responsible for the aroma that sets them apart from non-aromatic types. Aromatic rice also contains a complex mixture of volatile compounds over 100 including alcohols, aldehydes, hydrocarbons, ketones, and esters (Waheed *et al.* 2023). In Bangladesh, traditional aromatic rice varieties such as Kalizira, Tulshimala, Chinigura, Katarivog, and Basmati are widely cultivated and enjoy high market demand both domestically and internationally (Masud *et al.* 2024). These rice types are often used in festive dishes, religious offerings, and special exports due to their superior grain quality, fragrance, and soft texture. They command higher prices in local and export markets, contributing significantly to farmer income and rural livelihood development. However, most of these varieties are low yielding and highly sensitive to photo period, which restricts their adaptability and productivity. Many of the traditional aromatic rice varieties are also late maturing and susceptible to various biotic stresses. Therefore, improving the productivity of aromatic rice while preserving its premium grain quality is a priority in modern rice breeding and agronomic research (Hoque *et al.* 2024). Among the various biotic constraints in rice production, weeds are one of the most significant yield-limiting factors. In tropical and subtropical regions, the warm and moist conditions during the rice-growing season provide ideal conditions for the proliferation of a wide range of weed species. These include annual and perennial grasses, sedges, and broadleaf weeds, which grow vigorously and compete with rice for vital resources such as light, water, nutrients, and space (Chauhan and Johnson, 2021). Weeds can reduce rice yields by 30% to 70%, depending on the species, density, crop variety, and stage of infestation. In the Aman season, yield losses are often more severe due to less favorable field conditions and delayed manual weeding caused by frequent rains (Bishas *et al.* 2023). In some extreme cases, uncontrolled weed infestation can cause complete crop failure. Weed competition is most detrimental during the early growth stages of rice, typically between 15 to 45 days after transplanting. During this critical period, weeds grow rapidly, intercept sunlight, deplete soil moisture and nutrients, and suppress rice tillering and biomass accumulation. Some weeds like *Echinochloa crus-galli* (barnyard grass), *Cyperus iria* (rice flat sedge), and *Fimbristylis miliace*a are particularly competitive in direct-seeded and transplanted rice fields (Ali *et al.* 2024). Traditionally, weed control in rice fields in Bangladesh has relied on manual weeding and land preparation. Hand weeding and hoeing are still the most commonly used methods due to their precision and effectiveness, particularly in smallholder systems. However, these methods are highly labor-intensive and time-consuming. Manual weeding in a one-hectare field may require 150 to 200 labor hours, which significantly increases production costs (Paul *et al.* 2024). Moreover, labor scarcity during peak agricultural seasons often delays weeding operations, reducing their effectiveness. With the increasing migration of rural labor to urban areas and overseas employment, rural areas in Bangladesh are experiencing a chronic shortage of agricultural labor. Consequently, the reliance on manual weeding has become economically unviable and operationally unsustainable. Mechanical methods, such as power weeders and cono weeders, have shown promise, particularly in System of Rice Intensification (SRI) and aerobic rice systems. However, their adoption in traditional lowland Aman systems is limited due to waterlogged conditions, small plot sizes, and lack of training among farmers (Islam *et al.* 2018). Chemical weed control using herbicides is becoming increasingly popular in Bangladesh due to its convenience and relatively low labor requirement. Pre-emergence and post-emergence herbicides are now used in many large-scale farms. However, indiscriminate and repeated use of herbicides has raised serious concerns about herbicide resistance, soil degradation, residual toxicity, and human health risks (Kumar *et al.* 2020). The lack of awareness among farmers about herbicide selectivity, dosage, and application timing further exacerbates the problem. In light of the limitations of singular weed control approaches, Integrated Weed Management (IWM) has gained attention as a holistic and sustainable strategy. IWM involves the judicious combination of cultural, mechanical, biological, and chemical methods to manage weeds in a way that is environmentally sound, economically viable, and socially acceptable (Chauhan and Johnson, 2021). Recent studies have shown that integrated weed control can significantly reduce weed pressure, enhance rice growth and yield, and reduce dependency on herbicides (Ali *et al.* 2024). Moreover, it allows farmers to adapt weed management strategies based on local field conditions, labor availability, and economic considerations. In aromatic rice production systems, where quality is as important as quantity, integrated weed control is particularly beneficial. It ensures effective weed suppression without compromising grain aroma and quality due to excessive chemical use. This is especially critical for maintaining market acceptability and meeting export standards. Although aromatic rice production is gaining popularity in Bangladesh due to its high market value, its yield potential remains largely untapped due to poor weed management practices. Most farmers still rely on either hand weeding or herbicides, with limited awareness of integrated strategies. Research on the use of IWM in aromatic rice, particularly during the aman season, is limited and fragmented. Furthermore, the economic implications of IWM compared to conventional methods are not well studied, especially under real-field conditions. Given the escalating costs of labor and inputs, farmers need cost-effective weed control strategies that not only maximize yield but also ensure high grain quality. Therefore, a scientific evaluation of integrated weed control methods in aromatic rice production is crucial. It will provide insights into weed-crop dynamics, effectiveness of various methods, and their economic viability. This study aims to fill this knowledge gap by systematically assessing the effect of integrated weed control on the growth, yield, and economic returns of aromatic rice under aman conditions in Bangladesh.

- To determine the most effective method for controlling weeds in aromatic rice fields.
- To identify the optimal application rates and timings for these herbicides to maximize rice growth and yield.
- To assess the impact of chemical weed control on the overall health and quality of aromatic rice.

CHAPTER II
REVIEW OF LITERATURE

Effective weed management is one of the most crucial aspects of successful rice cultivation. As global demands for food security rise, the need to improve rice productivity sustainably has become more urgent, particularly in countries like Bangladesh where rice is the cornerstone of food and economic security. Weeds are among the most persistent biotic stresses that hinder crop performance. The introduction of Integrated Weed Management (IWM) offers a promising and sustainable alternative to conventional methods. This chapter provides a comprehensive review of relevant literature on aromatic rice, the impact of weeds; various weed control strategies, and the economic viability of integrated approaches.

2.1 Aromatic rice: importance and agronomic challenges

Aromatic rice comprises a unique group of rice varieties known for their distinct aroma, slender grain, and soft cooking texture. The aroma is primarily due to the presence of 2-acetyl-1-pyrroline (2-AP), a compound that gives the rice its characteristic fragrance (Waheed *et al.* 2023). Bangladesh is home to several traditional aromatic rice cultivars, including *Chinigura*, *Kalizira*, and *Katarivog,* which are cultivated mainly during the Aman season. These rice types are essential for both domestic consumption and export. However, most aromatic rice varieties are low-yielding, photoperiod-sensitive, and long-duration cultivars. Their narrow adaptability makes them more vulnerable to abiotic and biotic stresses, including weed competition. Islam *et al.* (2018) reported that aromatic rice has slower early-stage growth, which makes it less competitive against aggressive weeds. Furthermore, due to their traditional nature, many aromatic varieties are cultivated in low-input systems where modern weed management technologies are underutilized. As a result, these varieties often fail to achieve their full yield potential.

2.2 Effect of weed management on yield and yield attributes of rice

Weed is one of the limiting factors for successful rice production. Among various cultural practices, weeding play a vital role in the production and yield of rice through controlling the weeds which are favorable for rice production. To justify the present study attempts have been made to incorporate some of the important findings of different scientists and research workers in this country and elsewhere of the world.

2.2.1 Weed vegetation in rice

Al Mamun *et al.* (2021) carried out an experiment at the Agronomy Farm of Bangladesh Rice Research Institute, Gazipur, in winter season on Surjamoni and BRRI dhan29 and observed that *Paspalum distichum* was the dominating weed species in the experimental site.

Sharma *et al.* (2014) found their experiment that eight weed species to infest the crop were *Echinochloa crusgalli, Scirpus mucronatus, Cyperus difformis, Panicum repens, Digitaria ischaemum, Monochoria vaginalis, Leersia hexandra* and *Marsilia quadrifolia*. Among the weed species, *E. crusgalli* was the dominant one. They reported that the higher weed dry matter accumulation per unit area (7.98 g m^{-2}) was obtained from shorter variety and the lower weed dry weight (5.51 g m^{-2}) from the taller variety.

Hasanuzzaman *et al.* (2007) reported that 16 different weed species were observed in transplanted aman rice field where *Sagittaria guyanensis* and *Sphenoclea zeylanica* were the most dominant species.

Chander and Pandey (2001) stated that weed competition was severe in scented paddy culture, in view of its early slow growth rates.

2.2.2 Weed control efficiency by applying Pyrazosulfuron-ethyl (Superpower 10 WP), Pretilachlor (Superheat 500 EC) and others herbicide

Weed control efficiency is one of the important measurements of weed control in crop field. Weed control treatment ensures proper crop growth and profitable weed control by high weed control efficiency throughout the growing period. Weed control efficiency varies with weed control technology.

Al Mamun *et al.* (2021) conducted an experiment to find an effective and economic herbicide to control weeds. Becolor SG (Butachlor), Bouncer 10 WP (Pyrazosulfuron-ethyl) and Becofit 500 EC (Pretilachlor) were used to control weeds. The highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10 WP @ 150 g ha^{-1} which was 49% higher than control. BRRI dhan29 produced also the highest grain yield (5.92 t ha^{-1}) when treated with the same treatment which was 37% higher than control.

Tamilselvan and Budhar (2001) conducted an experiment to see the effect of pre-emergence herbicides (Butachlor @ 1.0 kg ha^{-1}, Butanil @ 1.0 kg ha^{-1}, Pretilachlor @

0.4 litre ha^{-1}, Pretilachlor @ 0.4 litre ha^{-1} + Safener and Anilofos @ 0.3 kg ha^{-1}) on rice. The herbicides were applied at 8 DAS. The density and dry weight of weeds at 40 DAS were lower in herbicide treated plots than in unweeded and hand weeded plots. The highest number of productive tillers $hill^{-1}$ was obtained with followed by Pretilachlor 0.40 litre ha^{-1}, Anilofos 0.3 kg ha^{-1}, and Butanil 1.0 kg ha^{-1}. The number of filled grain $panicle^{-1}$ was the highest with followed by Anilofos 0.3 kg ha^{-1} followed by Pretilachlor 0.40 litre ha^{-1} and Butanil 1.0 kg ha^{-1}.

Sharma and Bhunia (1999) reported that Pendimethalin @ 1.5 ka ha^{-1} plus one hand weeding resulted in highest weed control efficiency than any other treatments.

Ahmed *et al.* (1997) reported that higher weed control efficiency (90.35%) was observed in herbicides with one hand weeding treatment than sole herbicides or conventional weed control methods.

Alam *et al.* (1996) seemed that weed control efficiency was higher in two hand weeding (90.67%) than those of Oxadiazon and Cinosulfuron treatments.

Singh and Bhan (1992) found that two hand weeding resulted better weed control efficiency (72.3%) than Butachlor @, 1.5 kg ha^{-1} (54.40%) in rice under medium land condition.

Burhan *et al.* (1989) reported that Cinosulfuron @ 20 g ha^{-1} resulted in 85% control of *Monochoria vaginalis, Marsileaa crenata, Cyperus* spp., *Fimbristylis miliacea* and *Scirpus juncoides* but only 50-60% control of *Echinochloa crus-galli* in rice.

2.2.3 Effect of no weeding

Gogoi (1998) from Assam reported that different weed control practices significantly reduced the dry matter accumulation of weed and increased the rice yield over the un-weeded control in transplanted rice.

Singh and Kumar (1999) reported that maximum weed dry weight and the lowest grain yield was observed in the un-weeded control in the scented rice variety Pusa Basmati.

Sanioy *et al.* (1999) observed that control of weeds played a key role in improving the yield of rice because panicle m^{-2} increased 18% due to weed control over its lower level, number of filled grains $panicle^{-1}$ increased 32% due to weed control over its lower level and significant yield increase was observed (43%) with weed control.

Thomas *et al.* (1997) reported that rice weed competition for moisture was heavy during initial stages and yield losses from uncontrolled weeds might be as high as 74%.

Kamalam and Bridgit (1993) reported that the average reduction in grain yield due to weed competition was 56 percent.

2.2.4 Effect of hand weeding

Ashraf *et al.* (2006) made an experiment in Lahore, Pakistan, during 2004 and 2005 kharif seasons, for screening of herbicides for weed management in transplanted rice. In the second year the maximum control of weeds was 94.67% in the case of hand weeding. Regarding the number of tillers plant^{-1}, hand weeding resulted in 20.8 weeding to 16.6 for the control in the second year, whereas the highest number of grains panicle^{-1} was 135.50 during the second year. In terms of paddy yield, hand weeding gave the highest grain yield but remained statistically at par with certain herbicides.

Baloch *et al.* (2006) made an experiment in Pakistan to evaluate the effect of weed control practices on the productivity of transplanted rice. Among weed management tools, the maximum paddy yield was obtained in hand weeding, closely followed by Butachlor (Machete 60 EC during both cropping seasons).

Manish *et al.* (2006) said that *Alternanthera triandra, Echinochloa colorer, Fimhristylis miliacea* and *Xanthium strumarium* were the dominant weeds associated with the transplanted rice crop. Results revealed that hand weeding at 15 and 30 DAT (days after transplanting) gave the highest grain yield, straw yield and harvest index. Maximum weed density and dry matter were recorded in the unweeded control, while the minimum values were obtained with hand weeding at 15 and 30 DAT. Other than weed free condition, the highest grain yield (5.9 t ha^{-1}) was produced by BR 11 under two hand weeding.

Chandra and Solanki (2003) studied the effect of herbicides on the yield characteristics of direct sown flooded rice. The treatments were two hand weeding, Butachlor 2.0 kg ha^{-1} and Oxadiazon 0.8 kg ha^{-1}. They found that two hand weeding produced the highest ear length (23.49 cm), number of grains ear^{-1}, grain yield (33.65 g ha^{-1}), straw yield (65.35 g ha^{-1}) and harvest index (33.97%).

Bhowmick *et al.* (2002) revealed that *Echinochloa crus-galli*, *Cyperus iria*, *Cyperus rotundus* were the dominant weeds in transplanted rice. He observed that two hand weeding at 20 and 40 days after transplanting were able to control almost all categories of weeds.

Walker *et al.* (2002) reported that Reduced herbicide doses can still offer satisfactory weed control without compromising yield, with control efficiency often reaching 60-100%. However, effective suppression of diverse weed flora in rice usually requires a combination of pre- and post-emergence herbicides, as single applications are rarely sufficient.

Chander and Pandey (2001) showed that hand weeding was the most effective in mitigating the weed dry matter accumulation and also reported that higher grain and straw yield were obtained with hand weeding.

Hossain (2000) observed experiment oriented impact of different weeding approaches on rice like one hand weeding, two hand weeding, three hand weeding, Oxadiazon in combination with one hand weeding and observed that yield and yield contributing traits in rice production had upgraded by degrees with the higher frequency of hand weeding.

Balaswamy (1999) found that hand weeding twice at 20 and 40 days after transplanting resulted in low weed numbers, followed by herbicides

2.2.5 Effect of mechanical weeding

Khaliq *et al.* (2013) reported that data on weed dynamics and crop attributes were recorded following standard procedures. Weed density and biomass were significantly reduced under sole application of herbicides. So, the supplementing herbicide application with manual weeding in dry seeded rice fields can help to control weeds more effectively. To test this assumption, pre- and post-emergence herbicides applied either alone or supplemented with manual weeding were evaluated in field study. Pendimethalin at 1137 g a.i. per ha as pre-emergence (0 DAS), bispyribac sodium, penoxsulam, pyrazosulfuron ethyl and ethoxysulfuron ethyl at 30, 15, 30 and 30 g a.i. per ha, respectively, as early post emergence (15 DAS) was applied alone and supplemented with manual weeding (hoeing or pulling, 30 DAS). A weedy check and manual weeding thrice (15, 30 and 45 DAS) were included for comparison. However, supplementing herbicides with manual weeding further reduced both attributes to a much larger extent. Bispyribac sodium recorded higher weed suppression when it was followed by manual weeding.

Singh (2005) conducted an experiment at Bihar, India, during the wet season to assess the effectiveness of Beushening (a kind of mechanical weed control) in controlling weeds under rainfed lowland conditions as well as to make a comparison between Beushening and chemical weed control (i.e. 2,4-D and Butachlor). It was found that standard practice of Beushening along with one hand weeding 40 days after sowing, (DAS) was better in controlling weeds than other chemical treatments with or without one hand weeding 40 DAS and both (common and standard) practices of Beushening as effective as two hand weeding (25 and 40 DAS) in terms of grain yield, net return and benefit cost ratio.

Ahmed *et al.* (2003) said that Cinosulfuron, Pretilachlor and the BRRI push weeder performed better than farmer existing weed control practices of hand weeding with reduced weeding cost.

Sharma and Gogoi (1995) observed that the peg type dry land weeder and a twin wheel hoe gave best weed control which was comparable to that achieved with Butachlor + hand weeding.

Moorthy and Das (1992) stated that the finger weeder used twice resulted in the greatest weed control (80.7%) and grain yield (2.81 t ha^{-1}) but the paddy wheel hoe used gave twice higher straw yield (4.68 t ha^{-1}) where the paddy wheel hoe use twice resulted in the greatest weed control (80%), higher grain yield (1.65 t ha^{-1}) and straw yields (3.54 t ha^{-1}) and the finger weeder used twice resulted in the greatest weed control (80%), highest grain yield (1.65 t ha^{-1}) and straw yields (3.54 t ha^{-1})

2.3 Effect of weed management on the growth characteristics of aromatic rice

2.3.1 Plant Height

Plant height is an important growth parameter that reflects the vegetative vigor of rice plants and can be influenced by weed competition and herbicide application. In the present study, the plant height of Kalijira and Tulshimala was significantly affected by different pre-emergence and post-emergence herbicide treatments.

Among the two varieties, Tulshimala generally exhibited taller plant stature compared to Kalijira across all treatments. Plots treated with pre-emergence herbicides, such as Butachlor or Pendimethalin, showed better early weed control, which led to reduced competition for nutrients and light, resulting in enhanced plant height. Post-emergence herbicide application (e.g., Bispyribac-sodium) also contributed positively by suppressing late-emerging weeds, maintaining crop vigor throughout the vegetative stage.

The highest plant height was recorded in treatments combining herbicides with integrated nutrient management, particularly the use of 75% recommended dose of fertilizers (RDF) plus poultry manure at 2.5 t/ha, and 30-day-old seedling transplanting, aligning with findings from Sabil *et al.* (2021). This treatment improved plant growth by reducing weed pressure and enhancing nutrient uptake.

Although Kalijira displayed lower overall height due to its genetic characteristics, it responded positively to post-emergence herbicide treatments by showing moderate increases in plant height. Tulshimala, being more vigorous, benefited more prominently from both herbicide timings.

Thus, the combination of effective weed management and balanced nutrient supply significantly improved plant height in both varieties, emphasizing the importance of timely herbicide use in aromatic rice production.

2.3.2 Test Weight (1000-grain weight in grams)

Masud *et al.* (2024) reported that the 1000-grain weight of the aromatic rice variety BRRI dhan34 ranged from 11.26 g to 13.76 g, depending on cultivation practices. Under standard cultivation conditions without additional nutrient enhancement, the test weight was 11.26 g. However, the highest test weight (13.76 g) was achieved when 30-day-old seedlings were transplanted using 75% of the recommended dose of inorganic fertilizers in combination with poultry manure at 2.5 t/ha, suggesting the benefit of integrated nutrient management.

Sarkar *et al.* (2014) found the 1000-grain weight of BRRI dhan34 to be 11.5 g under general conditions, with improvements noted under integrated nutrient applications. These findings imply that grain filling and final grain weight can be significantly influenced by proper agronomic practices. While these studies primarily focus on nutrient management, they indirectly suggest that reduced competition from weeds—potentially through effective weed control—could also enhance assimilate partitioning to the grain, thereby improving test weight. In the context of this study, evaluating the impact of pre- and post-emergence herbicides on the test weight of Kalijira and Tulshimala varieties may reveal how weed pressure affects grain development in aromatic rice.

2.3.3 Number of grains per panicle

The application of pre-emergence and post-emergence herbicides had a noticeable effect on the number of grains per panicle in the two aromatic rice varieties, Kalijira and Tulshimala. Treatments involving pre-emergence herbicides (such as Butachlor or Pendimethalin) effectively suppressed early weed growth, ensuring that young rice seedlings established more vigorously. This early advantage contributed to improved panicle development and a higher number of grains per panicle compared to the untreated control.

Similarly, post-emergence herbicides (such as Bispyribac-sodium or Fenoxaprop-P-ethyl) were effective in controlling later-emerging weed species, particularly during the critical tillering and early panicle initiation stages. This reduction in mid-season weed pressure further contributed to enhanced nutrient availability and photosynthetic efficiency, resulting in improved grain setting.

Among the treatments, the highest number of grains per panicle was observed in plots where post-emergence herbicide was applied, especially in Tulshimala, indicating its stronger response to mid-season weed control. Kalijira also showed an increase in grain number per panicle under herbicide treatments, though slightly less pronounced. These results align with findings from Sabil *et al.* (2021), who reported increased grains per panicle under integrated nutrient management involving poultry manure and inorganic fertilizers. While the current study did not directly manipulate nutrient sources, the effective weed control achieved through herbicide use may have created similar favorable conditions for panicle development.

2.3.4 Grain yield

Chakrabortty *et al.* (2014), conducted at Sher-e-Bangla Agricultural University, the impact of different planting geometries under the System of Rice Intensification (SRI) was evaluated using BRRI dhan34. The experiment tested five plant spacings and found that the 40 cm × 40 cm spacing produced the highest grain yield (6.9 t/ha) along with maximum tiller count, dry matter accumulation, and filled grain number per panicle. In contrast, narrower spacing (25 cm × 25 cm) resulted in lower yield, suggesting that wider spacing under SRI allows better light penetration, root development, and reduced interplant competition, which collectively boost yield potential.

Although the present study did not focus on planting geometry, similar improvements in grain yield were observed under effective weed management through pre- and post-emergence herbicide applications. Weed control plays a parallel role by minimizing interspecific competition, thus allowing rice plants to better utilize nutrients, water, and light. In both Kalijira and Tulshimala, plots treated with post-emergence herbicides generally produced higher grain yields compared to untreated controls and even some pre-emergence treatments. This outcome likely reflects the herbicide's ability to suppress mid-season weed growth during critical reproductive stages, contributing to better grain filling and overall productivity.

2.3.5 Straw yield

Significant effects of seedling age on straw yield have been documented in previous studies. According to Saha *et al.* (2017) found younger seedlings tend to produce higher straw yield due to prolonged vegetative growth phases and better tillering. In contrast, older seedlings often result in lower biomass accumulation. For instance, maximum straw yield from 20-day-old seedlings compared to 30 and 40 days. Similarly, Roy *et al.* (2018) found that younger seedlings significantly outperformed older ones in straw yield, with 5.17 t/ha from younger seedlings. Rajesh and Thanunathan (2003) also concluded that 40-day-old seedlings produced the highest straw yield (5.63 t/ha) compared to 30- and 50-day-old seedlings. The study by Panigrahi *et al.* (2014) under SRI conditions showed minimal differences in straw yield between 10- and 15-day-old transplanted seedlings of BRRI dhan34.

In the current research, although seedling age was not a direct treatment factor, weed management through pre- and post-emergence herbicides showed a measurable effect on straw yield. Plots treated with herbicides, especially post-emergence applications, had higher straw yield compared to untreated control plots. This can be attributed to reduced competition from weeds during the key vegetative growth stages, which allowed the rice plants to utilize available resources more efficiently, resulting in increased plant height, tiller number, and ultimately higher biomass production.

Among the two varieties, Tulshimala generally produced slightly higher straw yield than Kalijira under herbicide treatments, indicating varietal differences in biomass accumulation and response to weed-free conditions. These findings suggest that effective herbicide-based weed control, though not directly altering seedling age, can mimic the benefits associated with younger, more vigorous seedlings by promoting healthy vegetative growth and improved straw yield.

2.3.6 Biological yield

Chakrabortty *et al.* (2014) conducted a field experiment at Sher-e-Bangla Agricultural University to evaluate the effect of seedling age and planting geometry under the System of Rice Intensification (SRI) on the biological yield of Boro rice. The study found that biological yield varied significantly with seedling age. The highest biological yield (9.84 t ha^{-1}) was recorded from 16-day-old seedlings, whereas the lowest (8.73 t ha^{-1}) was obtained from 30-day-old seedlings, highlighting the impact of early seedling vigor on total biomass production.

In a separate study by Ferdush *et al.* (2020) on BRRI dhan34, various row arrangements and nitrogen doses were tested. The experiment demonstrated that double row planting, combined with 80 kg N ha^{-1}, produced the maximum biological yield (11.96 t ha^{-1}). The increase was attributed to improved light interception and nutrient availability, which enhanced tiller production and overall biomass accumulation. The lowest biological yield and other yield parameters were observed in the triple row arrangement with no nitrogen application.

Although the current study focused primarily on weed management through pre- and post-emergence herbicides, a similar trend in biological yield was observed. Effective weed control resulted in significantly higher biological yield in both Kalijira and Tulshimala rice varieties compared to untreated controls. Among the herbicide treatments, post-emergence herbicides generally produced greater total biomass due to their ability to suppress mid-season weed growth, particularly during active tillering and panicle initiation stages. Reduced weed competition allowed the rice plants to access more nutrients and sunlight, promoting enhanced vegetative and reproductive growth, which collectively contributed to higher biological yield.

2.3.7 Harvest index

The Harvest Index (HI) is a critical physiological parameter in crop production, representing the efficiency with which a plant converts total biological yield into economic yield (grain). It is influenced by numerous factors including seedling age, nutrient management, water availability, and weed pressure. A higher HI indicates better resource partitioning toward grain development, a key determinant of crop productivity.

Islam *et al.* (2021) conducted a study at Noakhali Science and Technology University to evaluate the impact of seedling age on harvest index in Aus rice. The results revealed a significant effect of seedling age on HI, where 22-day-old seedlings recorded the highest HI (33.88%), while 30-day-old seedlings had the lowest (30.47%). This finding suggests that younger seedlings may allocate assimilates more efficiently toward grain rather than vegetative growth. Supporting this, Pramanik and Bera (2013) also reported higher HI values (45.19% and 47.00%) for 10-day and 15-day-old seedlings, respectively, further reinforcing the relationship between early vigor and assimilate partitioning.

In a separate context, Almeida *et al.* (2020) explored the role of chitosan foliar applications under water deficit conditions in BRRI dhan34, observing that the treatment at 140 mg L^{-1} significantly improved physiological responses, including gas exchange and antioxidant activity, and ultimately increased harvest index. This demonstrates that improved stress tolerance, whether through biochemical intervention or favorable growing conditions, can enhance partitioning efficiency and yield outcomes.

Moreover, Laila *et al.* (2020) studied nutrient management in aromatic rice and found that applying 50% of the recommended inorganic fertilizer combined with vermicompost at 3 t ha^{-1} significantly influenced dry matter production and physiological traits contributing to improved HI. These findings underscore the importance of balanced nutrition and resource availability in maximizing yield efficiency.

While the current study focuses on weed management rather than seedling age or nutrient supplementation, the impact on harvest index is comparably significant. Weeds compete with rice plants for light, nutrients, and moisture, often reducing the crop’s capacity to partition assimilate effectively into grain. In this experiment, plots treated with post-emergence herbicides, which maintained weed-free conditions during the crop’s critical reproductive stage, tended to record higher harvest index values compared to pre-emergence and untreated plots. The improvement in HI under effective weed control is likely due to reduced competition and enhanced photosynthetic efficiency, which allowed more assimilates to be directed toward grain production rather than vegetative biomass.

Both Kalijira and Tulshimala showed a positive response in HI under proper weed management, although Tulshimala demonstrated a slightly better assimilate partitioning under post-emergence herbicide application. These results support the idea that chemical weed control not only improves absolute yields but also enhances the physiological efficiency of the plant through better allocation of resources.

CHAPTER III

MATERIALS AND METHODS

This chapter outlines the materials and methodologies used to evaluate the effect of integrated weed control methods on the growth and yield performance of two aromatic rice varieties under Aman season conditions.

3.1 Experimental site and duration

The field experiment was conducted during the Aman season (July-December) of 2024 at the Agronomy Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh (Appendix I). The site is situated at 25°38′N latitude and 88°41′E longitude, at an elevation of 37.5 meter above sea level, and is part of Agro-Ecological Zone 1 (AEZ-1), also known as Old Himalayan Piedmont Plain. The soil at the experimental field belongs to the Old Himalayan Piedmont Plain (Agro ecological zone -1). The general soil type of the experimental field was non-calcareous dark gray floodplain. Topsoil was sandy loam in texture. Organic matter content was 1.48% and soil pH varies from 5.8-6.0. The land is above flood level and well drained. The land was previously used for rice cultivation under a rice-rice cropping pattern.

3.2 Climatic conditions

The climate is subtropical, characterized by three distinct seasons:

- A hot, humid summer (March-June)
- A monsoon (July-October)
- A cool, dry winter (November-February)

During the experimental period, the average temperature ranged from 27°C to 32°C, relative humidity ranged from 75% to 92%, and the total rainfall was about 1100 mm. Weather data were recorded from the HSTU Meteorological Observatory and are summarized in Appendix II.

3.3 Planting materials

Two traditional aromatic rice varieties were selected as

- **V_1:** Kalizira
- **V_2:** Tulshimala

Both varieties are renowned for their fragrance, fine grains, and premium market value but are relatively low-yielding and sensitive to weed competition. Seeds were collected from the Bangladesh Rice Research Institute (BRRI) and tested for viability. A wet-bed nursery was prepared for raising 30-day-old seedlings prior to transplanting.

3.4 Herbicide Application

- **Pre-emergence herbicide**: Pretilachlor applied at 3 DAT (Days After Transplanting) using a flat-fan nozzle with 500 mL/ha water.
- **Post-emergence herbicide**: Penoxsulam @ 200 mL/ha applied at 14 DAT.

3.4.1 Short description of Superheat 500 EC (Pretilachlor)

Pretilachlor (Superheat 500 EC) used in this study as herbicide is described below:

IUPAC Name: 2-chloro-N-(2, 6-diethylphenyl)-N-(2-propoxyethyl) acetamide

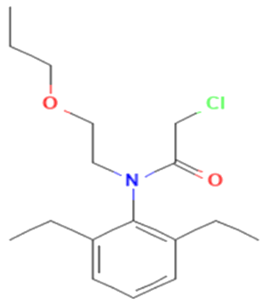

Figure 1. 2D structure of Pretilachlor

3.4.1.1 Mode of action

Pretilachlor belongs to the chloroacetamide class of herbicides, which inhibits growth and reduces cell division. For this reason, weeds cannot grow in the field properly.

3.4.1.2 Uses

Pretilachlor offers reliable and selective pre-emergence broad spectrum which excellent action to control of annual grasses, some sedges and broadleaf weeds (e.g. *Echinochloa* spp. *Cyperus difformis*, *Monochoria vaginalis*) for high yield in transplanted and dry-sown rice cropping systems.

3.4.1.3 Application time and rate of Superheat 500 EC

It is used at 3 days after transplanting at the rate of 1 liter ha^{-1}.

3.4.1.4 Method of application in experimental plot

In this experiment, 1 liter ha^{-1} dose of Superheat 500 EC with water was used at 3 DAT in 4-5 cm standing water as pre-emergence herbicide for the control of weeds by hand sprayer and weeds were allowed to grow with the crop for the first 39 DAT. At 40 days one hand weeding was done and afterwards no weeding was done till harvesting. Time of herbicide application and hand weeding was recorded.

3.4.2 Short description of Penoxsulam

Penoxsulam (Trade Name: Upper Klem) used in this study as herbicide is described in below

IUPAC name: 2-(2,2-difluoroethoxy)-N-(5,8-dimethoxy-triazolo[1,5-c]pyrimidin-2-yl)-6-(trifluoromethyl) benzenesulfonamide.

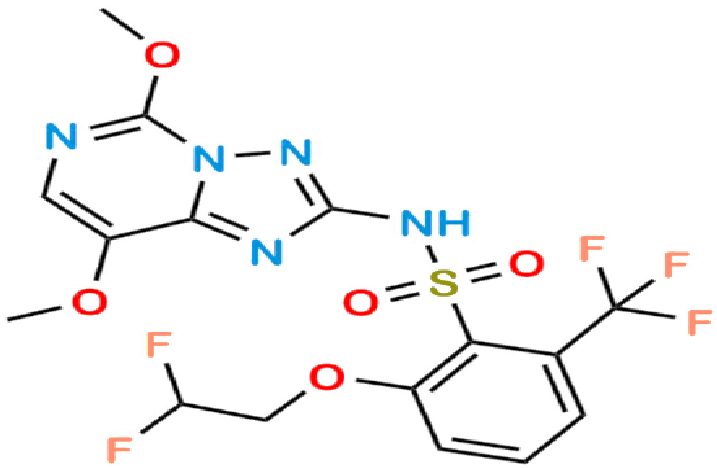

Figure 2. 2D structure of Penoxsulam

3.4.2.1 Mode of Action:

Penoxsulam is a systemic post-emergence herbicide that is absorbed through the leaves and roots of young weeds. It translocates throughout the plant and inhibits the acetolactate synthase (ALS) enzyme, which disrupts the synthesis of essential branched-chain amino acids. This results in the gradual death of the weed within 10–15 days, without harming rice plants.

3.4.2.2 Uses

Penoxsulam is effective against a broad spectrum of weeds, including:

- Sedges (Cyperus spp.)
- Broadleaf weeds
- Grassy weeds (*Echinochloa spp*., etc.)
- It is widely used in transplanted rice fields as a post-emergence herbicide.
- Can be used in aromatic rice varieties like Tulsimala and Kalizira with caution (recommended trial application on small plots first).

3.4.2.3 Application Time and Rate:

- Timing: 10-15 Days After Transplanting (DAT)
- Dose: 200-250 ml/ha Or 80-100 ml per bigha (local unit)
- Water Condition: Maintain 3–5 cm standing water during and 2–3 days after application

3.4.2.4 Method of application in experimental plot

Upper Klem herbicide was applied at a rate of 200 mL per hectare on the 12th day after transplanting (12 DAT). The required amount of herbicide was mixed thoroughly with clean water and uniformly sprayed over the plot using a knapsack sprayer. At the time of application, a standing water level of 4-5 cm was maintained to ensure effective herbicide activity. The yellowing of weeds was observed within 3 to 5 days after application, and complete control was achieved within 10 to 15 days. To manage any possible weed regrowth, one hand weeding was carried out at 30 DAT.

3.5 Treatments

Two factors were included in the experiment, namely, weed management and variety. The treatments were designated as follows:

- **Factor A:** (Variety)

V_1 = Tulshimala

V_2 = Kalizira

- **Factor B:** (Weed Management Methods)

T_1 = Control

T_2 = Pre-emergence herbicide + one hand weeding at 20 DAT

T_3 = Post-emergence herbicide + one hand weeding at 40 DAT

T_4 = Pre-emergence herbicide + post-emergence herbicide

- **Treatment combinations:** (8)

  1) V_1T_1
  2) V_1T_2
  3) V_1T_3
  4) V_1T_4
  5) V_2T_1
  6) V_2T_2
  7) V_2T_3
  8) V_2T_4

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block contained 8 plots, where 8 treatment combinations were assigned randomly. In total, the experiment consisted of 24-unit plots. Each plot measured 3 m x 4 m, with a 0.5 m gap between adjacent blocks and plots (Figure 1).

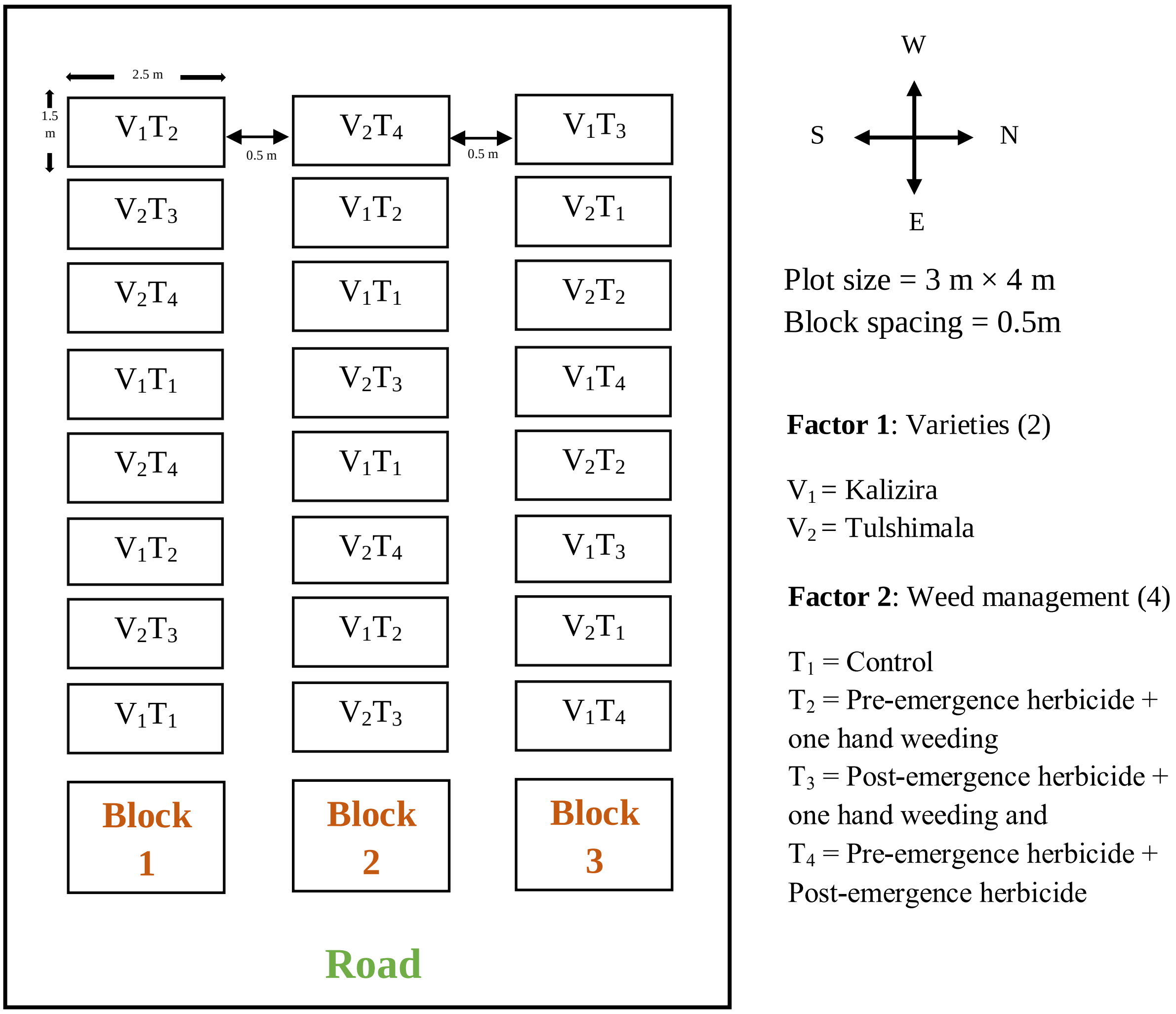

Figure 3. Field layout of the experiment

3.7 Conduction of experiment

3.7.1 Collection of seed

Seeds were collected from the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

3.7.2 Raising of seedling

Seedlings were raised in well prepared seedbed at the Agronomy research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur. Before sowing in the nursery, seeds were soaked in water for 24 hours and then kept in gunny bags in dark conditions. After sprouting, the seeds were sown in the wet seedbed on 24th June 2024. Proper operations were done as per necessary.

3.7.3 Land preparation

The land was first opened in 22nd June 2024. Firstly, two ploughs were given with a tractor mounted disc plough. After a few days the land was further ploughed and cross ploughed with the country plough followed by laddering to get a good puddle condition. Weeds and stubbles were removed from the field prior to transplanting seedlings. The bounds around individual plot were made firm enough to control water movement between plots.

3.7.4 Fertilizer application

The whole amount of triple super phosphate (60 kg P_2O_5 ha^{-1}) muriate of potash (40 kg K_2O ha^{-1}), gypsum (15 kg ha^{-1}) two types of compost were applied at final land preparation time for properly mixed with soil of the field. The nitrogen was applied in the form of urea as experimental specification. One third of urea was applied during the final land preparation and the rest urea as were applied in two equal installments at 35 and 55 DAT, respectively.

Recommended Dose of others inorganic fertilizers are-

- Urea- 100 kg ha^{-1}
- TSP- 60 kg ha^{-1}
- MOP- 40 kg ha^{-1}

3.7.5 Uprooting of seedling

The seedbeds were made wet by applications of water both in the morning and in the evening on the previous days of uprooting the seedlings. Seedlings were uprooted carefully without causing an injury to the roots and were kept in shade.

3.7.6 Preparation of experimental plots

The experiment was laid out on 28 July 2024 according to the experimental design.

3.7.7 Transplanting

Thirty-five days old seedlings of two aromatic rice varieties were transplanted with 3 seedlings per hill on 31 July 2024.

3.7.8 Intercultural operations

The experimental field was frequently visited to observe the growth performance of rice plants as well as insects and diseases infestation in the field. The experimental field was weeded twice to keep the crop-weed competition at a minimum level Top dressing of urea was done on the days previously mentioned. The crop was irrigated during the growth period when necessary. Pesticide application was applied when pest infestation during the growth and development period of the crop.

3.7.9 Harvesting

Maturity of crops was determined when 80% of the seeds became golden yellow in color. The crop was harvested at full maturity on 5 December 2024, and it was done plot wise and was tagged for proper identification for threshing, cleaning and drying. The yields of both grain and straw were recorded after thoroughly drying in the sun.

3.7.10 Processing

After harvest, grains were threshed, cleaned and sun dried to record the grain yield plot. The grain was adjusted to 14 % moisture content. The straw was also sun dried to record the straw yield plot. Grain and straw yield plot were converted to t ha^{-1}

3.8 Collection of data before harvest

The data of the crop were collected as follows:

3.8.1 Plant sampling

Five hills (excluding border hills) from each plot were selected randomly and tagged just after transplanting for measuring counting tillers at 30 days intervals from 30 DAT, 60 DAT and 90 DAT.

3.8.2 Tiller counting

Tillers were counted from the selected hills at 30 days intervals from 30 DAT, 60 DAT, 90 DAT and final harvesting time.

3.9 Collection of data at harvest

3.9.1 Data were recorded on the following crop characteristics

i. Plant height (cm)
ii. Number of total tillers hill^{-1}
iii. Number of effective tillers hill^{-1}
iv. Number of non-effective tillers hill^{-1}
v. Length of panicle (cm)
vi. Grains panicle^{-1}(no.)
vii. 1000-grain weight (g)
viii. Grain yield (t ha^{-1})
ix. Straw yield (t ha^{-1})
x. Biological yield (t ha^{-1})
xi. Harvest index (%)

Data on individual plant parameters (i-vii) were recorded from selected hills of each plot, those on grain yield, straw yield, biological yield and harvest index were recorded from the whole plot at harvest, and qualitative characters were recorded from selected grain.

3.10 Procedure of recording data

A brief outline of the data recording procedure is given below:

3.10.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 30, 60, 90 DAT and at harvest stage. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The plant height was measured from the ground level to the tip of the panicle.

3.10.2 Number of total tillers hill^{-1}

Number of the tillers hill^{-1} was recorded at 30, 60, 90 DAT and at harvest stage as the average of randomly selected 5 plants from the inner rows of each plot.

3.10.3 Number of effective tillers hill^{-1}

The panicles that had at least one grain were considered as effective tillers.

3.10.4 Number of non-effective tillers hill^{-1}

The panicles, which had no grain, were regarded as non- Effective tillers.

3.10.5 Panicle length (cm)

The length of panicle was measured with a meter scale from 5 selected plants and the average value was recorded as per plant. Panicle length was recorded from the basal node of the rachis to the apex of each panicle.

3.10.6 Number of grains per panicle

Presence of any food material in the spikelet was considered as grain and total numbers of grains present on each panicle are counted.

3.10.7 1000-grain weight (g)

One thousand clean dried grains were counted from the seed stock obtained from five sample plants of each plot and weighed by using an electrical balance.

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

Grains obtained from each unit plot were suns dried and weighed carefully. The dry weight of grains of selected plants was added to respective unit plot to record the final grain yield plot. The grain yield was finally converted to t ha^{-1}.

Grain yield (t ha^{-1}) = $\frac{Grain\ yield\ per\ unit\ plot\ (kg) \times 10000}{Area\ of\ unit\ plot\ in\ square\ meter \times 1000}$

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

Straw obtained from each unit plot including the straw of sample plants of respective unit plot was dried in sun and weighed to record that final straw yield plot and finally converted to t ha^{-1}

Straw yield (t ha^{-1}) = $\frac{Straw\ yield\ per\ unit\ plot\ (kg) \times 10000}{Area\ of\ unit\ plot\ in\ square\ meter \times 1000}$

3.10.10 Biological yield (t ha^{-1})

Grain yield and straw yield were altogether regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1}).

3.10.11 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.* 1985)

Harvest Index (%) = $\frac{Grain\ Yield\ \times 100}{Biological\ Yield}$

3.11 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on growth, yield and quality parameters of aromatic rice. The mean values of all the characters were statistically analyzed by following the analysis of variance (ANOVA) technique and mean differences were adjusted by Duncan's Multiple Range Test (DMRT) using the Statistix 10 computer package program. The mean differences among the treatments were compared by the least significant difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter outlines and contrasts the results obtained from the study conducted to assess the impact of integrated weed management on the growth and yield performance of aromatic rice. The results are systematically presented through various tables and figures. Comprehensive statistical evaluations, including ANOVA for all recorded parameters, are included in Appendices IV to IX. Each set of findings is explained under relevant sub-sections, with supporting data displayed in Tables 1 to 12 and Figures 1 to 8.

4.1 Growth parameters

4.1.1 Weed species infestation in the experimental field

The experimental field, characterized by conditions conducive to the cultivation of aromatic rice, also supported vigorous growth of diverse weed flora. This favorable environment promoted the proliferation of various weed species, which intensified competition with crop plants, particularly under higher weed densities. A total of twelve weed species, representing distinct botanical families, were recorded in the experimental plots. Detailed information including their local names, scientific names, families, morphological types, and life cycles is presented in Table 1. Weed density varied markedly across different weed management practices and nitrogen application levels. Prominent weed species identified included *Echinochloa colonum*, *Cyperus rotundus*, *Scirpus mucronatus*, *Cynodon dactylon*, *Echinochloa crus-galli*, *Commelina benghalensis*, and *Paspalum distichum*. Notably, *Digitaria ischaemum* and *Paspalum distichum* exhibited dominance throughout the crop growth period, while *Ludwigia parviflora* and *Paspalum distichum* were prevalent at harvest. Among the twelve recorded species, six were grasses and two were sedges, as summarized in Table 2.

Table 1: Weed species found in the experimental field in aromatic rice

Sl. No.	Bengali name	English name	Scientific name	Family name	Life cycle	Type
1	Dubra	Bermuda grass	*Cynodon dactylon*	Poaceae	Perennial	Grass
2	Boro Shama	Barnyard grass	*Echinochloa cruss-galli*	Poaceae	Annual	Grass
3	Choto Shama	Jungle rice	*Echinochloa colonum*	Poaceae	Annual	Grass
4	Khude Anguli	Smooth scrab	*Digitaria ischaemum*	Poaceae	Annual	Grass
5	Gitla grass	Joint grass	*Paspalum distichum*	Poaceae	Annual	Grass
6	Malanch	Aligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Annual	Grass
7	Sushi shak	4-leaved water clover	*Marsilea quadrifolia*	Marsilesceae	Annual	Grass
8	Mutha	Nutsedge	*Cyperus rotundus*	Cyperaceae	Perennial	Sedge
9	Chechra	Bog bulrush	*Scirpus mucronatus*	Cyperaceae	Perennial	Sedge
10	Keshuti	White eclipta	*Eclipta prostrata*	Asteraceae	Annual or Perennial	Broad leaf
11	Kanabashi	Spiderwort	*Commelina bengalensis*	Commelinaceae	Annual	Broad leaf
12	Panilong	Water primerose	*Ludwigia parviflora*	Onagraceae	Annual	Broad leaf

4.1.2 Plant height

4.1.2.1 Effect of variety

Plant height varied significantly among the rice varieties, as shown in Figure 1 and Appendix III. Tulshimala (V_2) recorded the longest plant height at all growth stages (25.92, 61.68, 105.50, and 159.30 cm at 30, 60, 90 DAT and at harvest, respectively). While Kalizira (V_1) showed the shortest (24.92, 56.93, 101.22, and 152.07 cm) height among the same observation days. These differences indicate the influence of genetic variation among aromatic rice cultivars on plant growth. Similar observations were made by Masud *et al.* (2024), who reported that varietal traits significantly affected plant height in aromatic rice.

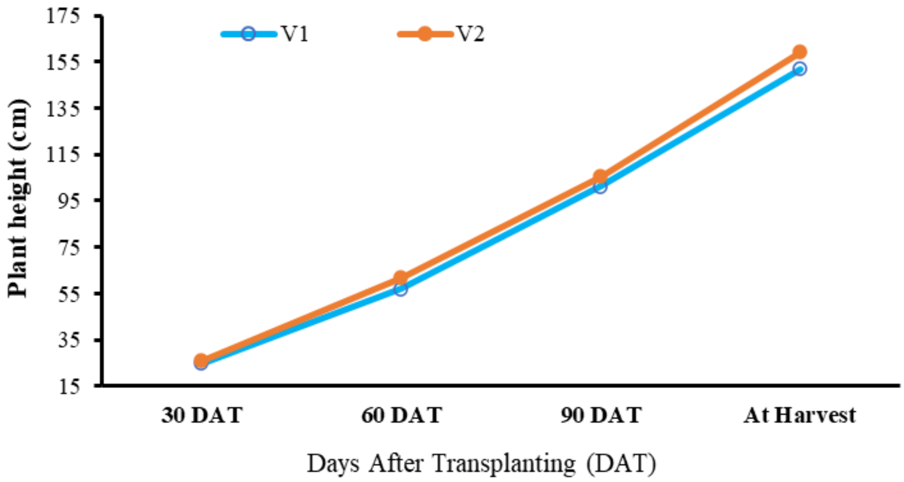

Figure 1: Effect of variety on the plant height of aromatic rice at different days after transplanting ($LSD_{0.05}$ = 1.23, 1.95, 2.80 and 3.48 at 30, 60, 90 DAT and at harvest, respectively)

Here, V_1 = Kalizira, V_2 = Tulshimala

4.1.2.2 Effect of weed management

Plant height in rice was significantly influenced by weed management, as shown in Figure 2 and detailed in Appendix III. The results revealed that treatment T_3 rendered the longest plant height recording 26.33 cm at 30 DAT, 62.33 cm at 60 DAT, 108.00 cm at 90 DAT and 165.93 cm at harvest. Conversely, the shortest plants were viewed under T_1 (control) measuring 24.67 cm, 55.67 cm, 95.00 cm and 135.67 cm at the respective growth stages. Previous studies support the beneficial role of post-emergence herbicide and hand weeding in promoting rice growth. For instance, Khavanekar *et al.* (2024)

demonstrated that specific post emergence herbicides, such as Pyribenzoxim 3% + Penoxsulam 2% EC at 1500 ml/ha, result in significantly greater rice plant height at multiple growth stages. Mostafa *et al.* (2024) found post emergence herbicide application proved to be the best and most budget-friendly for plant height increase in rice. Similarly, Mir *et al.* (2023) reported significant improvements in rice height when post emergence herbicide was applied. Srinithan *et al.* (2020) further demonstrated that application of penoxsulam + cyhalofop butyl@135 g ha^{-1} led to significant increase in plant height.

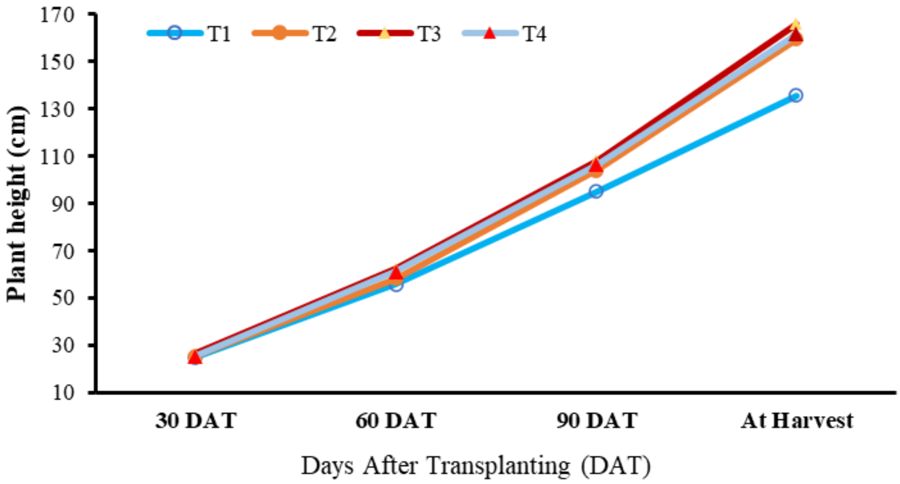

Figure 2: Effect of weed management on the plant height of aromatic rice ($LSD_{0.}05$= 1.74, 2.76, 3.96 and 4.92 at 30, 60, 90 DAT and at harvest, respectively)

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

Table 2: Interaction effect of variety and different weed management on the plant height of aromatic rice at different days after transplanting

Treatment combination	Plant height (cm)			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
V_1T_1	24.00b	54.33e	92.67de	132.33d
V_1T_2	25.00ab	56.00de	102.67cd	156.60c
V_1T_3	25.33ab	59.33cd	105.33abc	161.67bc
V_1T_4	25.33ab	58.07cde	104.20bc	157.67c
V_2T_1	25.33ab	57.00cde	97.33de	139.00d
V_2T_2	25.67ab	60.40bc	105.33ab	162.53bc
V_2T_3	27.33a	65.33a	110.67a	170.20a
V_2T_4	25.33ab	64.00ab	108.67ab	165.46ab
LSD $_{(0.05)}$	2.64	3.90	5.61	6.96
CV (%)	5.53	3.76	3.10	2.55
LS	NS	*	*	*

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS= Non-significant

4.1.2.3 Interaction effect of variety and weed management

Rice plant height showed significant differences across the applied treatments, highlighting a strong interaction between variety and weed management practices (Table 2 and Appendix III). The maximum plant heights viewed at 30, 60, 90 (DAT) and harvest (27.33, 65.33, 110.67 and 170.20 cm) were observed under the treatment combination V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding), which was statistically close with V_2T_4 treatment across all growth stages. In contrast, the shortest plants were observed in the treatment combination of V_1T_1 (24, 54.33, 92.67 and 132.33 cm) at 30, 60, 90 DAT and at harvest respectively.

Research indicates that applying post-emergence herbicide resulted in the tallest plant height 104.4 cm under postemergence herbicide (Ali *et al.* 2024). While Osman *et al.* (2020) found multiple varietal-herbicide combinations in post-transplant rice showed numerical increases in plant height when using early post-emergence herbicides.

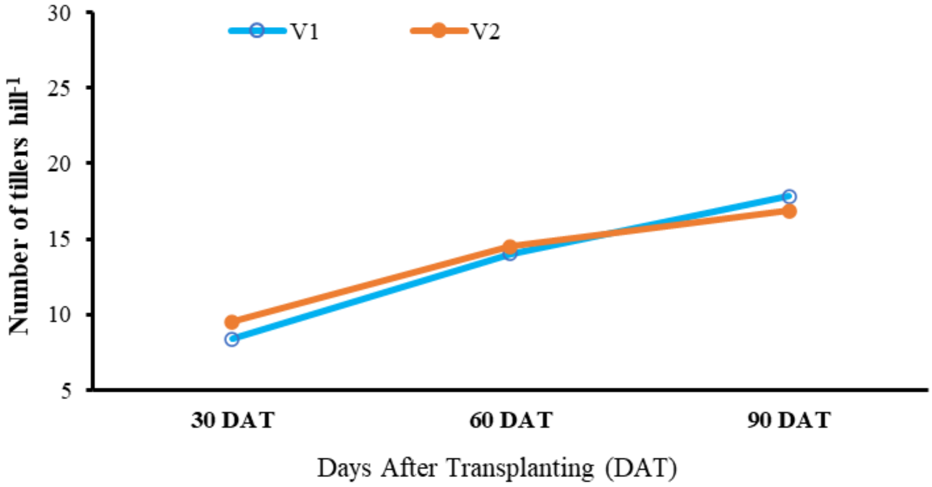

Figure 3: Effect of variety on the number of tillers hill^{-1} of aromatic rice at different days after transplanting (LSD $_{(0.05)}$ = 1.06, 1.16 and 1.83 at 30, 60, 90 DAT, respectively)

Here, V_1 = Kalizira, V_2 = Tulshimala

4.1.3 Number of tillers hill^{-1}

4.1.3.1 Effect of variety

Statistically significant variation in the number of hill-1 tillers was observed among the different aromatic rice varieties (Figure 3 and Appendix IV). The results indicated that variety V_2 (Tulshimala) showed the highest number of tillers hill^{-1} (9.52 and 14.49) at 30 and 60 days after transplanting (DAT). Interestingly at 90 DAT, the trend shifted with variety V_1 (Kalizira) recording the highest tiller hill^{-1} 17.84. Despite this late advantage, V_1 (Kalizira) consistently produced the lowest number of tillers at the earlier stages, with only 8.37 and 14.03 tillers hill^{-1} at 30 and 60 DAT, respectively. The results clearly highlight the important role of varietal traits in influencing tiller production. This observation is consistent with Masud *et al.* (2024), who found that genetic variation among rice varieties significantly affects the tiller number across different environmental conditions. Similarly, Fathima and Lavanya (2022) reported that tiller number plant^{-1} can vary widely due to differences in varietal characteristics.

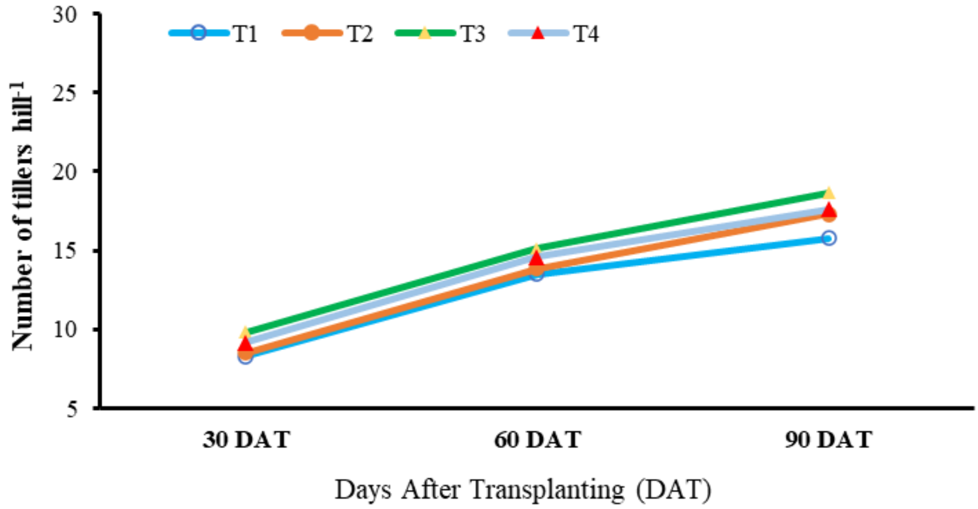

Figure 4: Effect of weed management on the number of tillers hill^{-1} of aromatic rice ($LSD_{0.05}$ = 1.74, 2.76, 3.96 and 4.92 at 30, 60, 90 DAT and at harvest, respectively)

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

4.1.3.2 Effect of weed management

The number of tillers hill^{-1} in aromatic rice was significantly influenced by the weed management practice (Figure 4 and Appendix IV). Among the treatments, T_3 (Post-emergence herbicide + one hand weeding) showed the highest tiller hill^{-1} (9.82, 15.13 and 18.67), at 30, 60 and 90 days after transplanting. In contrast, T_1 (control) rendered in the lowest tiller count (8.28, 13.48 and 15.79) at 30, 60 and 90 days after transplanting. These findings align with previous research indicating that varietal differences can significantly influence the number of tillers per hill in aromatic rice. (Masud *et al.* 2024). Furthermore, Hossain *et al.* (2008) found local traditional aromatic varieties showed significant varietal differences in total tillers hill^{-1}.

Table 3: Interaction effect of variety and different weed management on the number of tillers hill^{-1} of aromatic rice at different days after transplanting

Treatment combination	Number of tillers hill^{-1}		
	30 DAT	60 DAT	90 DAT
V_1T_1	7.23c	12.20b	16.16a
V_1T_2	8.60bc	14.00ab	17.62a
V_1T_3	8.87abc	15.07a	18.96a
V_1T_4	8.80abc	14.87a	18.62a
V_2T_1	9.33abc	14.77ab	15.42a
V_2T_2	8.47bc	13.67ab	17.02a
V_2T_3	10.77a	15.20a	18.38a
V_2T_4	9.53ab	14.33ab	16.60a
LSD $_{(0.05)}$	2.13	2.32	3.66
CV (%)	13.60	14.26	12.07
LS	NS	NS	**

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS= Non-significant

4.1.3.3 Interaction effect of variety and weed management

Statistically significant difference in the number of tillers hill^{-1} was observed as a result of the interaction between rice variety and weed management practice (Table 3 and Appendix IV). Among the treatment combinations, the highest tiller hill^{-1} at 30 and 60 DAT (10.77 and 15.20) was observed in V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding). Which was statistically comparable (9.53 and 14.33 at 30 and 60 DAT) to the results of V_2T_4 (Tulshimala with pre and post-emergence herbicide). Conversely, the fewest tillers hill^{-1} (7.23 and 12.20) emerged from V_1T_1 (control) at 30 and 60 DAT. Interestingly at 90 DAT, no significant difference found between the combination treatments. Although the highest tiller hill^{-1} (18.96) obtained V_1T_3 and lowest (16.16) from V_1T_1 (control).

4.2 Yield contributing parameters

4.2.1 Effective tillers hill^{-1}(no.)

4.2.1.1 Effect of variety

A statistically significant variation in the number of effective tillers hill^{-1} was observed among the different rice aromatic varieties (Table 4 and Appendix V). Notably, the variety V_2 (Tulshimala) produced the highest number of effective tillers hill^{-1} (13.90), while the lowest count, (11.17) was recorded for variety V_1 (Kalizira). This finding underscores the inherent genetic influence on effective tillering capacity among rice genotypes. The observed variation in effective tiller production is consistent with earlier findings, where varietal differences significantly influenced tiller number (Masud *et al.* 2024; Islam *et al.* 2018). These statistically significant differences are important, as the number of effective tillers plays a key role in determining grain yield and overall crop productivity.

Table 4: Effect of variety on the number of effective tillers hill^{-1} and number of non-effective tillers hill^{-1}

Treatments	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
V_1	11.17b	4.19a
V_2	13.90a	3.79b
LSD $_{(0.05)}$	1.61	1.17
CV (%)	14.69	33.42
LS	**	NS

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS= Non-significant

Here, V_1 = Kalizira, V_2 = Tulshimala

4.2.1.2 Effect of weed management

The number of effective tillers hill^{-1} was statistically influenced by different weeding management (Table 5 and Appendix V). Among the treatments, T_3 (Post-emergence herbicide + one hand weeding) showed the highest number of effective tillers hill^{-1} (16.89), conversely the lowest (4.32) seen in T_1 (control). These findings highlight the importance of weeding in promoting tiller development. Ali *et al.* (2024) observed that, application of post-emergence herbicide significantly improve in effective tillering numbers in rice.

Table 5: Effect of weed management on the number of effective tillers hill^{-1} and number of non-effective tillers hill^{-1}

Treatments	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
T_1	4.32c	7.97a
T_2	14.10b	2.84b
T_3	16.89a	2.24b
T_4	14.83ab	2.93b
LSD $_{(0.05)}$	2.28	1.65
CV (%)	14.69	33.42
LS	**	**

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

** = Significant at 1% level of significance, * = Significant at 5% level of significance.

4.2.1.3 Interaction effect of variety and weeding management

The number of effective tillers hill^{-1} in aromatic rice was significantly affected by the interaction between variety and weeding management (Table 6 and Appendix V). The treatment combination V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding) executed the highest number of effective tillers hill^{-1} (18.67). In contrast, the lowest number of effective tillers (2.88) was viewed under V_1T_1 (Kalizira with no weeding). These results are consistent with Ali *et al.* (2024) and Islam *et al.* (2018), who reported that interaction effect of variety and post-emergence herbicide influence yield attributes, particularly effective tillering in rice.

4.2.2 Non-effective tillers hill^{-1}(no.)

4.2.2.1 Effect of variety

Statistically significant variation observed in the number of non-effective tillers hill^{-1} across different aromatic rice varieties (Table 4 and Appendix V). Among the tested varieties, V_1 (Kalizira) noticed the highest number of non-effective tillers hill^{-1} (4.19). In contrast, the lowest number of non-effective tillers hill^{-1} (3.79) was seen in V_2 (Tulshimala). These findings underscore the influence of varietal characteristics on non-effective tillering in rice. The findings of this study supported with the research conducted by Ma *et al.* (2020), who highlighted that varietal differences significantly affect non-effective tiller production in rice.

4.2.2.2 Effect of weed management

The number of non-effective tillers hill^{-1} in aromatic rice varieties were statistically influenced by the weed management practices (Table 5 and Appendix V). Among the treatments, T_1 (control) showed the highest number of non-effective tillers hill^{-1} (7.97), whereas the lowest non-effective tiller (2.24) was observed in T_3 (Post-emergence herbicide + one hand weeding), which was statistically similar with T_2 and T_4. Moreover, recent research by Sultana *et al.* (2024) reinforces that no weeding can indeed lead to an increase in non-effective tillers per hill^{-1}. Also, Osman *et al.* (2020) observed non-effective tillers hill^{-1} was significantly higher under no-weeding compared to fully-weeded plots in rice.

Table 6: Interaction effect of variety and weeding management on number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}

Treatment combination	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}
V_1T_1	2.88c	8.95a	12.92e	154.37b
V_1T_2	13.28b	2.60b	18.17d	173.13ab
V_1T_3	15.10b	2.17b	21.08bc	177.29a
V_1T_4	13.40b	3.07b	20.17c	171.60ab
V_2T_1	5.75c	7.00a	13.11e	171.31ab
V_2T_2	14.92b	3.08b	21.44bc	170.97ab
V_2T_3	18.67a	2.31b	24.13a	178.98a
V_2T_4	16.27ab	2.80b	22.20b	174.35ab
LSD $_{(0.05)}$	3.22	2.34	1.83	20.29
CV (%)	14.69	33.42	5.45	6.76
LS	*	*	*	NS

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS= Non-significant

4.2.2.3 Interaction effect of variety and weed management

Statistically significant difference in the number of non-effective tillers hill^{-1} was noticed as a result of the interaction between aromatic rice variety and weeding management practices (Table 6 and Appendix V). The treatment combination V_1T_1 (Kalizira with no weeding) resulted in the highest number of non-effective tillers hill^{-1} (8.95), which was statistically similar with V_2T_1 (Tulshimala with no weeding) treatment (7.00). Conversely, the lowest number (2.17) was noted in V_1T_3 (Kalizira with post-emergence herbicide + one hand weeding), suggesting that post-emergence herbicide may be more favorable for productive tillering. These outcomes support the findings of Salam *et al.* (2024), who highlighted that both variety and weeding regime had a statistically significant effect on the number of non-effective (non-productive) tillers per hill^{-1} in rice. While, Ferdous *et al.* (2016) confirmed that interaction between cultivar and weed control was significant for effective tillering, as no weeding causes higher number no-effective tillers in rice.

4.2.3 Panicle length (cm)

4.2.3.1 Effect of variety

Panicle length showed statistically significant variation among the aromatic rice varieties, as illustrated in Figure 5 and detailed in Appendix V. Among the tested variety, V_2 (Tulshimala) showed the longest panicle (20.22 cm), while V_1 (Kalizira) rendered the shortest, at 18.08 cm. The results align with previous findings by Wang *et al.* (2024), who noted that varietal differences can significantly increase panicle length in rice, emphasizing the importance of genotype selection in optimizing morphological features.

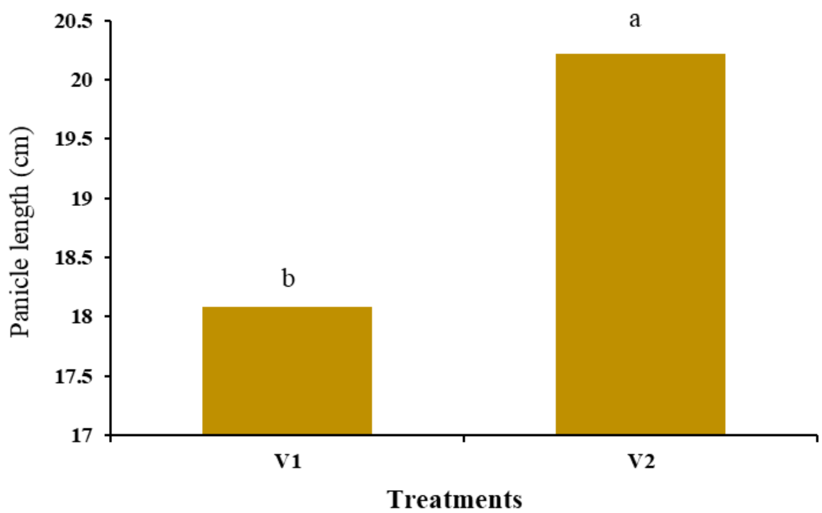

Figure 5: Effect of variety on the panicle length of aromatic rice ($LSD_{0.05}$ = 0.91)

Here, V_1 = Kalizira, V_2 = Tulshimala

4.2.3.2 Effect of weed management

Panicle length was statistically significant by different weed management (Figure 6 and Appendix V). The longest panicle length (22.61 cm) was seen by T_3 (Post-emergence herbicide + one hand weeding) and shortest (13.01 cm) was viewed in T_1 (control) treatment. Several studies have reported similar observations align with the result. For instance, the use of Super Power 10 WP in aromatic Aman rice notably increased panicle length compared to untreated and hand-weeded plots (Islam *et al.* 2018). Similarly, post-emergence applications of herbicides such as bispyribac-sodium and fenoxaprop-p-ethyl

+ Almix have been shown to perform on par with manual weeding in improving panicle attributes in rice (Deva and Khwaja 2014).

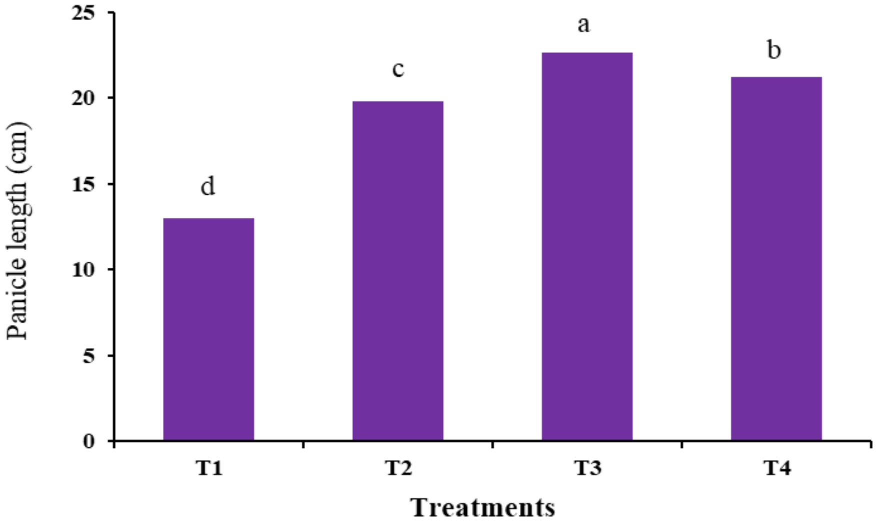

Figure 6: Effect of weed management on the panicle length of aromatic rice ($LSD_{0.05}$ = 1.29)

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

4.2.3.3 Interaction effect of variety and weed management

The interaction between aromatic rice varieties and weed management had a statistically significant effect on panicle length, as presented in Table 6 and Appendix V. Significantly, the longest panicle (24.13 cm) was observed by the treatment combination V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding). In contrast, the shortest panicle length (12.92 cm) was viewed in the V_1T_1 treatment (Kalizira with no weeding), closely followed by V_1T_4 (Kalizira with pre and post emergence herbicide), which showed a statistically similar value of 13.11 cm. The interaction between rice varietals and weed management can significantly influence panicle length. Salam (2020) found that the application of early post-emergence herbicides followed by hand weeding resulted in increased panicle length (21.82 cm) compared to control treatments, indicating the positive effect of herbicide use on panicle growth in rice. While Ferdous *et al.* (2016) reported that, variety × weed-control significant interactions increase panicle length in rice.

4.2.4 Number of grains panicle^{-1}

4.2.4.1 Effect of variety

The number of grains panicle^{-1} did not vary statistically due to effect of variety shown in Table 7 and Appendix V. Although, V_2 (Tulshimala) produced the highest number (173.90) of grains panicle^{-1}. While the lowest number of grains panicle^{-1} (169.10) was counted from V_1 (Kalizira).

Table 7: Effect of variety on the number of grains panicle^{-1}, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}

Treatments	Number of grains panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Treatments
V_1	169.10a	149.13b	19.97a	V_1
V_2	173.90a	162.64a	12.51b	V_2
LSD $_{(0.05)}$	10.15	6.87	5.82	LSD $_{(0.05)}$
CV (%)	6.76	6.26	16.90	CV (%)
LS	NS	*	**	LS

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1% * = Significant at 5%, NS= Non-significant

Here, V_1 = Kalizira, V_2 = Tulshimala

4.2.4.2 Effect of levels of weed management

The number of grains panicle^{-1} was found to vary statistically significantly across different weed management, as presented in Table 8 and Appendix V. Among the treatments, T_3 (post-emergence herbicide + one hand weeding) stood out by producing the statistically highest grain panicle^{-1}, averaging 178.14 grains. In contrast, the lowest grain number panicle^{-1} (162.84) was observed under the T_1 treatment (control). Recent studies have consistently reported that effective weed management through post-emergence herbicides enhances panicle development and grain formation, primarily due to reduced weed competition during the early vegetative stages (Jehangir *et al.* 2024). Similarly, post-emergence herbicides were found to improve grain formation by allowing better light interception and nutrient availability during the panicle initiation phase in rice (Tirkey *et al.* 2024).

Table 8: Effect of weed management on the number of grains panicle^{-1}, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}

Treatments	Number of grains panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Treatments
T_1	162.84b	135.48b	27.36a	T_1
T_2	172.05ab	159.21a	13.75b	T_2
T_3	178.14a	166.33a	13.39b	T_3
T_4	172.98ab	162.52a	10.46b	T_4
LSD $_{(0.05)}$	14.35	9.72	8.24	LSD $_{(0.05)}$
CV (%)	6.76	6.26	16.90	CV (%)
LS	NS	**	**	LS

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

** = Significant at 1% * = Significant at 5%, NS= Non-significant

4.2.4.3 Interaction effect of variety and weed management

The interaction between different aromatic rice varieties and weed management had a statistically significant effect on the number of grains panicle^{-1}, as shown in Table 6 and Appendix V. Among the treatment combinations, V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding) showed the highest grain panicle^{-1}, reaching 178.98 grains. In contrast, the lowest grain number panicle^{-1} (154.37) was viewed under the V_2T_3 treatment (Kalizira with no weeding).

4.2.5 Number of filled grains panicle^{-1}

4.2.5.1 Effect of variety

The number of filled grains panicle^{-1} showed statistically significant variation across different aromatic rice varieties, as presented in Table 7 and Appendix VI. Among the tested varieties, V_2 (Tulshimala) rendered the highest number of filled grains panicle^{-1} (162.64). In contrast, V_1 (Kalizira) showed the lowest count, with only 149.13 filled grains panicle^{-1}. This distinct variation highlights the influence of genetic diversity among rice cultivars. Supporting this observation, Masud *et al.* (2024) emphasized that such genetic variability can lead to statistically significant changes in grain filling capacity, contrasting the significance of genotype selection.

4.2.5.2 Effect of weed management

The number of filled grains panicle^{-1} exhibited statistically significant variation across different weed management, as detailed in Table 8 and Appendix VI. Notably, treatment T_3 (Post-emergence herbicide + one hand weeding) compiled the highest (166.33) number of filled grains panicle^{-1}, which was statistically similar with T_2 and T_4. Conversely, the lowest value was observed in T_1 (control), with only 135.48 filled grains panicle^{-1}.

4.2.5.3 Interaction effect of variety and weed management

A statistically significant interaction was observed between aromatic rice varieties and weed management in relation to the number of filled grains panicle^{-1}, as illustrated in Table 9 and Appendix VI. Among all treatment combinations, the highest filled grain was observed in V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding), resulting in an average of 173.67 filled grains panicle^{-1}. Alternately, the lowest filled grain was seen in V_1T_1 (Kalizira with no weeding), with an average of 126.28 grains panicle^{-1}. These findings suggest that while post-emergence herbicide and hand weeding can significantly enhance grain filling in rice.

4.2.6 Number of unfilled grains panicle^{-1}

4.2.6.1 Effect of variety

Statistically significant variation showed by the number of unfilled grains panicle^{-1} across different aromatic rice varieties, as presented in Table 7 and Appendix VI. Among the varieties, V_1 (Kalizira) stood out by producing the highest number of unfilled grains panicle^{-1} (19.97), a result that was statistically superior to the others. In contrast, V_2 (Tulshimala) showed the lowest count, with only 12.51 unfilled grains panicle^{-1}. This distinct variation highlights the influence of genetic diversity among rice cultivars. Kumar *et al.* (2020) mentioned that genetic diversity among cultivars can result in statistically significant variations in grain filling capacity, pointing to its crucial role in shaping crop performance.

4.2.6.2 Effect of weed management

The number of unfilled grains panicle^{-1} showed statistically significant variation across different weed management practices, as detailed in Table 8 and Appendix VI. Notably, treatment T_1 (control) rendered the highest number of unfilled grains panicle^{-1}, averaging 27.36. Conversely, the lowest value was observed in T_3 (Post-emergence herbicide + one hand weeding), with only 13.39 unfilled grains panicle^{-1} which was statistically closer to T_4 and T_2.

4.2.6.3 Interaction effect of variety and weed management

Statistically significant interaction was observed between aromatic rice varieties and weed management in relation to the number of unfilled grains panicle^{-1}, as illustrated in Table 9 and Appendix VI. Among all treatment combinations, the highest unfilled grain (27.57) count was observed in V_1T_1 (Kalizira with no weeding), which was statistically similar with V_1T_1 (Tulshimala with no weeding) with 27.15 unfilled grains panicle^{-1}. In contrast, the lowest unfilled grain count was seen in V_2T_2 (Tulshimala with pre and post-emergence herbicide), with an average of 6.82 grains panicle^{-1}.

Table 9: Interaction effect of variety and weed management on the number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}

Treatment combination	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}
V_1T_1	126.28e	27.57a
V_1T_2	153.22cd	19.92ab
V_1T_3	159.00bc	18.29abc
V_1T_4	157.50bcd	14.10bc
V_2T_1	144.17d	27.15a
V_2T_2	165.19abc	7.58c
V_2T_3	173.67a	8.49bc
V_2T_4	167.53ab	6.82c
LSD $_{(0.05)}$	13.74	11.65
CV (%)	6.26	16.90
LS	NS	*

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS= Non-significant

4.2.7 1000-grain weight

4.2.7.1 Effect of variety The 1000-grain weight was influenced by the aromatic rice variety, as evident from Figure 7 and Appendix VI. Among the tested varieties, the highest 1000-grain weight (13.17 g) was compiled in variety V_2 (Tulshimala), while the lowest (11.98 g) was observed in V_1 (Kalizira). The results clearly demonstrate that varietal differences have a statistically significant effect on grain weight. This variation aligns with earlier studies, which indicate that rice genotypes naturally differ in their morphological characteristics influencing grain size and weight (Soundharya *et al.* 2024; Chhodavadiya *et al.* 2023).

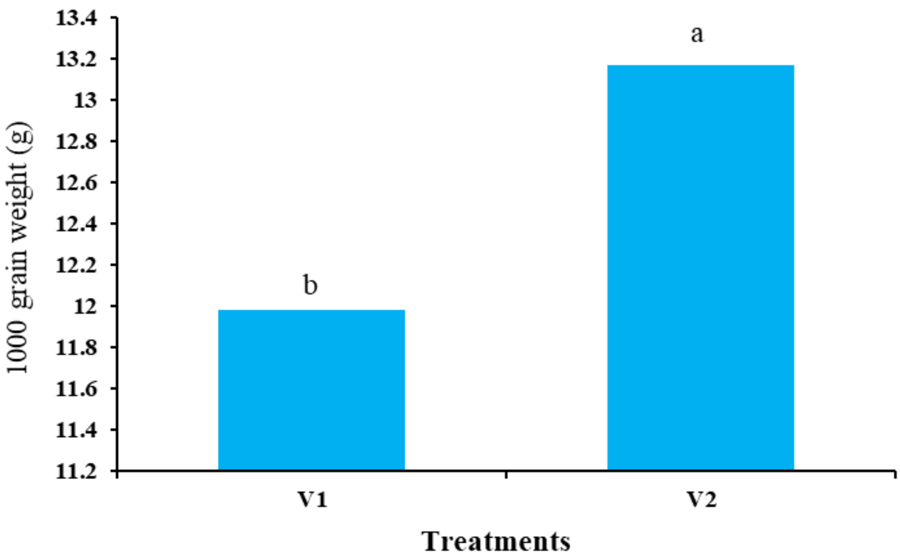

Figure 7: Effect of variety on 1000 grain weight of aromatic rice ($LSD_{0.05}$ = 0.37)

Here, V_1 = Kalizira V_2 = Tulshimala

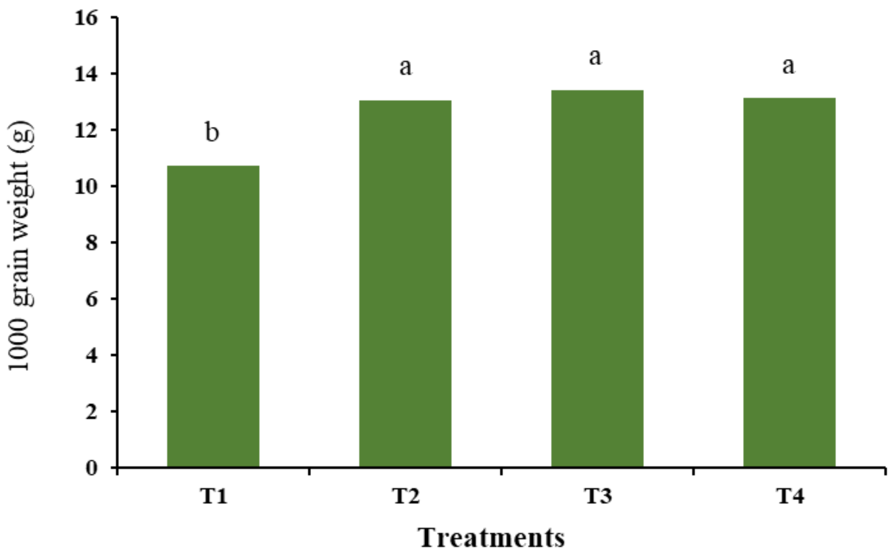

Figure 8: Effect of weed management on 1000grain weight of aromatic rice ($LSD_{0.05}$ = 0.53)

Here, V_1 = Kalizira, V_2 = Tulshimala

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

4.2.7.2 Effect of weed management

There was marked difference found in terms of 1000-grain weight of rice affected by different weed management practices (Figure 8 and Appendix VI). It was observed that the T_3 (Post-emergence herbicide + one hand weeding) treatment rendered the highest 1000-grains weight (13.41 g). While the T_1 (control) treatment showed the lowest 1000 grain weight (10.73 g).

4.2.7.3 Interaction effect of variety and boron

Table 12 showed the impact of the interaction between rice aromatic variety and different weed managements on 1000-grain weight (refer to Appendix VI). Among the different treatment combinations, the highest 1000-grains weight (14.04 g) was seen from the treatment combination of V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding). Conversely, the lowest 1000-grain weight (9.90 g) was observed from the treatment combination of V_1T_1 (Kalizira with no weeding).

4.3 Yield parameters

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

4.3.1.1 Effect of variety

Grain yield was statistically influenced by the different aromatic rice varieties, as shown in Table 10 and Appendix VII. Among the tested varieties, V_2 (Tulshimala) resulted the highest grain yield 2.19 t ha^{-1}, while V_1 (Kalizira) recorded the lowest yield of 1.83 t ha^{-1}. The considerable variation observed in grain yield can be primarily linked to the genetic diversity among the varieties, which significantly influences their yield capacity. Similar conclusions were drawn by Masud *et al.* (2024) and Murshida *et al.* (2017), who highlighted the pivotal role of varietal characteristics in shaping rice yield outcomes.

Table 10: Effect of variety on the grain yield, straw yield, biological yield and harvest index of aromatic rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	1.83b	5.42b	7.97a	24.60b
V_2	2.19a	5.78a	7.26b	27.18a
LSD $_{(0.05)}$	0.13	0.22	0.33	1.30
CV (%)	7.33	4.51	5.03	5.76
LS	**	**	**	**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1%, * = Significant at 5%, NS = Non-significant

Here, V_1 = Kalizira V_2 = Tulshimala

4.3.1.2 Effect of weed management

The yield of grains influenced by different weed management strategies showed statistically significant differences (Table 11 and Appendix VII). The T_3 (Post-emergence herbicide + one hand weeding) treatment observed the highest grain production (2.40 t ha^{-1}). While, the treatment with the lowest grain production (1.17 t ha^{-1}) was from T_1 (control). Ali *et al.* (2024) demonstrated that grain yield increased notably under post-emergence herbicide treatment, reaching 4.73 t ha^{-1}, which was significantly higher than the no-weeding control (3.27 t ha^{-1}), indicating its effectiveness in enhancing yield. Similarly, Salam *et al.* (2020) noted that, application of early post-emergence herbicide significantly enhanced grain yield in rice, highlighting its effectiveness in weed suppression and yield improvement.

Table 11: Effect of weed management the grain yield, straw yield, biological yield and harvest index of aromatic rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	1.17c	5.04b	6.21b	18.51c
T_2	2.17b	5.74a	7.91a	27.44b
T_3	2.40a	5.79a	8.20a	29.31a
T_4	2.30ab	5.84a	8.14a	28.29ab
LSD $_{(0.05)}$	0.18	0.31	0.47	1.84
CV (%)	7.33	4.51	5.03	5.76
LS	**	**	**	**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1% level of significance, * = Significant at 5% level of significance.

Here, T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

4.3.1.3 Interaction effect of variety and weed management

Statistically significant variation on grain yield of rice was observed by the interaction effect of variety and weed management (Table 12 and Appendix VII). It was revealed that the highest grain yield (2.61 t ha^{-1}) was rendered from the treatment combination of V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding). Where the lowest grain yield (0.94 t ha^{-1}) was observed from the treatment combination of V_1T_1 (Kalizira with no weeding).

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

4.3.2.1 Effect of variety

Statistically significant difference was found due to different variety of aromatic rice on straw yield (Table 10 and Appendix VII). Resul showed that, the highest straw yield (5.78 t ha^{-1}) was observed from the variety V_2 (Tulshimala). Where the lowest straw yield (5.42 t ha^{-1}) was viewed from the variety V_1 (Kalizira).

Table 12: Interaction effect of variety and weed management on 1000 grain weight, grain yield, straw yield, biological yield and harvest index

Treatment combination	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1T_1	9.90e	0.94e	4.36b	5.30d	17.40d
V_1T_2	12.54c	2.05c	5.67a	7.72bc	26.61c
V_1T_3	12.78bc	2.19bc	5.74a	7.93ab	27.68bc
V_1T_4	12.69c	2.16c	5.92a	8.08ab	26.71c
V_2T_1	11.57d	1.40d	5.73a	7.12c	19.62d
V_2T_2	13.53ab	2.29bc	5.81a	8.09ab	28.27bc
V_2T_3	14.04a	2.61a	5.85a	8.46a	30.94a
V_2T_4	13.52d	2.45ab	5.81a	8.21ab	29.72ab
$LSD_{(0.05)}$	0.75	0.26	0.44	0.67	2.61
CV (%)	3.40	7.33	4.51	5.03	5.76
LS	*	**	**	**	*

In a column, means with similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

** = Significant at 1% level of significance, * = Significant at 5% level of significance

Here, V_1 = Kalizira, V_2 = Tulshimala; T_1= Control (No weeding), T_2= Pre-emergence herbicide + one hand weeding, T_3= Post-emergence herbicide + one hand weeding, T_4= Pre-emergence + post-emergence herbicides

4.3.2.2 Effect of weed management

Significant impact was observed in terms of straw yield influenced by weed management practice under the study (Table 11 and Appendix VII). Among the different treatments, the highest straw yield (5.84 t ha^{-1}) was compiled from T_4 (pre-emergence + post emergence herbicide) treatment. Which was statistically similar with T_2 and T_3. While the lowest straw yield (5.04 t ha^{-1}) was observed from T_1 (control) treatment.

4.3.2.3 Interaction effect of variety and weed management

The interaction between aromatic rice varieties and varying boron levels had a significant effect on straw yield (Table 12 and Appendix VII). Among the different treatment combinations, the highest straw yield (5.92 t ha^{-1}) was found from the treatment combination of V_1T_4 (Kalizira with pre- and post-emergence of herbicide) which was statistically similar with V_1T_2, V_1T_3, V_2T_1, V_2T_2, V_2T_3 and V_2T_4. In contrast, the lowest straw yield (4.36 t ha^{-1}) was observed in V_1T_1, where Kalizira was treated with no weeding.

4.3.3 Biological yield (t ha^{-1})

4.3.3.1 Effect of variety

Biological yield varied significantly across the tested aromatic rice varieties (refer to Table 10 and Appendix VII). The highest yield was viewed in variety V_2 (Tulshimala) at 7.97 t ha^{-1}, while variety V_1 (Kalizira) showed the lowest yield of 7.26 t ha^{-1}. The observed differences in biological yield highlight the influence of varietal characteristics on overall plant productivity.

4.3.3.2 Effect of weed management

Biological yield of rice was significantly influenced by weed management practices (Table 11 and Appendix VII). Based on the results, the T_3 treatment (Post-emergence herbicide + one hand weeding) yielded the maximum biological output (8.20 t ha^{-1}), which was statistically identical with T_2 and T_4. While the T_1 treatment (control) yielded the lowest biological yield (6.21 t ha^{-1}). This result was aligned with previous work by Nur-A-Alam *et al.* (2024), who also reported increased biological yield in rice with effective post-emergence herbicide application combined with hand weeding.

4.3.3.3 Interaction effect of variety and weed management

The significant difference was notable for biological yield of rice because of interaction effect of variety and weed management (Table 12 and Appendix VII). It was remarked that the highest biological yield (8.46 t ha^{-1}) was rendered from the treatment combination of V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding). In contrast, the minimum yield of 5.30 t ha^{-1} was found in V_1T_1 (Kalizira with no weeding).

4.3.4 Harvest index (%)

4.3.4.1 Effect of variety

The harvest index varied significantly among the different aromatic rice varieties (Table 10 and Appendix VII). Variety V_2 (Tulshimala) showed the highest harvest index at 27.18%, whereas the lowest value of 24.60% was observed in variety V_2 (Kalizira).

4.3.4.2 Effect of weed management

Significant differences in the harvest index of aromatic rice were observed under various weed management (refer to Table 11 and Appendix VII). The treatment with post-emergence herbicide + one hand weeding (T_3) led to the maximum harvest index of 29.31%. Conversely, the lowest harvest index (18.51%) was observed in the control treatment (T_1). This trend indicates that post-emergence herbicide + one hand weeding enhances the efficiency of dry matter conversion into grain yield. Align with this result, Mostafa *et al.* (2024) found that post-emergence herbicide combined with one hand weeding significantly improved the harvest index, highlighting its effectiveness in enhancing dry matter partitioning toward grain yield in boro rice.

4.3.4.3 Interaction effect of variety and weed management

The combined influence of aromatic rice variety and weed management significantly affected the harvest index, as shown in Table 12 and Appendix VII. The highest harvest index (30.94%) was seen in the V_2T_3 (Tulshimala with post-emergence herbicide plus one hand weeding) treatment. In contrast, the lowest harvest index, 17.40%, was observed in V_1T_1, which was statistically similar with V_2T_1. The result highlights the importance of weeding management specific to each variety to ensure better biomass allocation towards grain production.

CHAPTER IV

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was conducted from July to December 2024 at the research field of the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, with the objective of assessing the effects of integrated weed management practices on the productivity of various aromatic rice varieties. The experiment followed a factorial arrangement involving two factors: *viz.* two rice varieties- V_1 (Kalizira) and V_2 (Tulshimala) and four weed management strategies (T_1 = control, T_2 = Pre-emergence herbicide + one hand weeding, T_3 = Post-emergence herbicide + one hand weeding 20 DAT and T_4 = Pre-emergence herbicide + Post-emergence herbicide 40 DAT). The experiment followed a randomized complete block design (RCBD) with three replications, and data were recorded on diverse growth parameters, yield and yield-related traits. Different varieties have significantly influenced on growth, yield and yield contributing parameters. Considering the growth parameters, the longest plant height (25.92, 61.68, 105.50, and 159.30 cm at 30, 60, 90 DAT and at harvest, respectively) had resulted from the variety V_2 (Tulshimala). The shortest plant height (24.92, 56.93, 101.22 and 152.07 cm at 30, 60, 90 DAT and at harvest, respectively) was seen from the variety V_1 (Kalizira). Again, the highest number of tillers hill^{-1} (9.52 and 14.49 at 30, 60 DAT) noticed from V_2 (Tulshimala). Interestingly at 90 DAT, the highest tiller hill^{-1} (17.8) obtained with V_1 (Kalizira). Where V_1 (Kalizira) showed the lowest number of (8.37 and 14.03) tillers hill^{-1} at 30 and 60 DAT. In the case of yield and yield contributing parameters, the highest number effective of tillers hill^{-1} (13.90), panicle length (20.22), number of grains panicle^{-1} (173.90), number of filled grains panicle^{-1} (162.64), were found from V_2 (Tulshimala). Conversely, the lowest number effective of tillers hill^{-1} (11.17), panicle length (18.08), number of grains panicle^{-1} (169.10), number of filled grains panicle^{-1} (149.13), were observed from V_1 (Kalizira). While the highest number non-effective of tillers hill^{-1} (4.19), number of unfilled grains panicle^{-1} (19.97) were rendered from V_1 (Kalizira). Conversely, the lowest non-effective number of tillers hill^{-1} (3.79), number of unfilled grains panicle^{-1} (12.51) were viewed from V_2 (Tulshimala). On the other hand, the highest 1000-grain weight (13.17 g), grain yield (2.19 t ha^{-1}), straw yield (5.78 t ha^{-1}) and harvest index (27.18) were obtained from the variety V_2 (Tulshimala). In contrast, lowest 1000-grain weight (11.98 g), grain yield (1.83 t ha^{-1}), straw yield (5.42 t ha^{-1}) and harvest index (24.60) were observed from the variety V_1 (Kalizira). For biological yield the variety V_1 (Kalizira) rendered the maximum values (7.97 t ha^{-1}) and variety V_2 (Tulshimala) resulted the lowest yield (7.26 t ha^{-1}). Different integrated weed management strategies had also significant influence on growth, yield and yield contributing parameters. Considering the growth parameters, the longest plant height (26.33, 62.33, 108.00 and 165.93 cm at 30, 60, 90 DAT and at harvest) was achieved from T_3 treatment (post-emergence herbicide + one hand weeding). The lowest plant height (24.67. 55.67, 95.00 and 135.67 cm at 30, 60, 90 DAT and at harvest) were observed from T_1 treatment (control). The highest number of tillers $hill^{-1}$ (9.82, 15.13 and 18.67 at 30, 60, 90 and DAT) were compiled from T_3 treatment (Post-emergence herbicide + one hand weeding). On the other hand, the lowest number of tillers $hill^{-1}$ (8.28, 13.48 and 15.79 at 30, 60, 90 and DAT) were observed from T_1 treatment (control). In case of yield and yield contributing parameters, the highest number effective of tillers $hill^{-1}$ (16.89), panicle length (22.61), number of grains $panicle^{-1}$ (178.14), number of filled grains $panicle^{-1}$ (166.33) were found from T_3 treatment. While the highest number non-effective of tillers $hill^{-1}$ (7.97), number of unfilled grains $panicle^{-1}$ (27.36) seen from (T_1). The treatment T_1 (control) showed the lowest effective number of tillers $hill^{-1}$ (4.32), panicle length (13.01), number of grains $panicle^{-1}$ (135.48), number of filled grains $panicle^{-1}$ (166.33). While the lowest number non-effective of tillers $hill^{-1}$ (2.24), number of unfilled grains $panicle^{-1}$ (13.39) observed from (T_3). On the other side, the highest 1000-grain weight (13.41 g), grain yield (2.40 t ha^{-1}), biological yield (8.20 t ha^{-1}) and harvest index (29.31) were obtained from the T_3 treatment. While highest straw yield (5.78 t ha^{-1}) obtained from (T_4). Conversely, the lowest 1000-grain weight (10.73 g), grain yield (1.17 t ha^{-1}), straw yield (5.04 t ha^{-1}), biological yield (6.21 t ha^{-1}) and harvest index (18.51) were seen from the T_1 (control) treatment. Interaction effect of variety and integrated weed management strategies had also significantly influenced on growth, yield and yield contributing characters of aromatic rice. Considering growth parameters, the longest plant height (27.33, 65.33, 110.67 and 170.20 cm at 30, 60, 90 DAT and at harvest) was viewed from V_2T_3 treatment (Tulshimala with post-emergence herbicide + one hand weeding). In contrast, the shortest plant height (24, 54.33, 92.67 and 132.33 cm at 30, 60, 90 DAT and at harvest) was seen from V_1T_1 (Kalizira with no weeding) treatment. The highest number of tillers $hill^{-1}$ (10.77 and 15.20 cm at 30, 60 DAT) was achieved from V_2T_3 treatment (Tulshimala with post-emergence herbicide + one hand weeding). While at 90 DAT the highest number of tillers hill^{-1} (18.96) obtained V_1T_3. In contrast, the lowest number of tillers hill^{-1} (7.23, 12.20 and 16.16 at 30, 60 and 90 DAT) was rendered from V_1T_1 (Kalizira with no weeding) treatment. In case of yield and yield contributing parameters, the highest number effective of tillers hill^{-1} (18.67), panicle length (23.13), number of grains panicle^{-1} (178.98), number of filled grains panicle^{-1} (173.67) viewed from V_2T_3 treatment. While the highest number non-effective of tillers hill^{-1} (8.95), number of unfilled grains panicle^{-1} (27.57) found from (V_1T_1). The treatment V_1T_1 (control) observed the lowest number effective of tillers hill^{-1} (2.88), panicle length (12.92), number of grains panicle^{-1} (154.37), number of filled grains panicle^{-1} (126.28). While the lowest non-effective number of tillers hill^{-1} (2.17) from V_1T_3 and lowest number of unfilled grains panicle^{-1} (6.82) seen from (V_2T_4) treatment. On the other hand, the highest 1000-grain weight (14.04 g), grain yield (2.61 t ha^{-1}), biological yield (8.46 t ha^{-1}) and harvest index (30.94) were obtained from the V_2T_3 treatment. While the highest straw yield (5.92 t ha^{-1}) observed from (V_1T_4) treatment. Conversely, the lowest 1000-grain weight (9.90 g), grain yield (0.94 t ha^{-1}), straw yield (4.36 t ha^{-1}), biological yield (5.30 t ha^{-1}) and harvest index (17.40) were rendered from the V_1T_1 (Kalizira with no weeding) treatment.

5.2 Conclusion

The research revealed that the Tulshimala variety (V_2) showed the most favorable growth and yield characteristics, including longest plant height, highest number of tillers hill^{-1}, number effective of tillers hill^{-1}, panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, 1000-grain weight, grain yield, straw yield and harvest index.

The implication of post-emergence herbicide + one hand weeding at 20 DAT (T_3), markedly improved plant development, leading to increased plant height, number of tillers and other yield contributing parameters. Notably, the interaction between variety and post-emergence herbicide + one hand weeding at 20 DAT treatment executed significant effects, with the V_2T_3 combination demonstrating the most favorable growth and yield performance.

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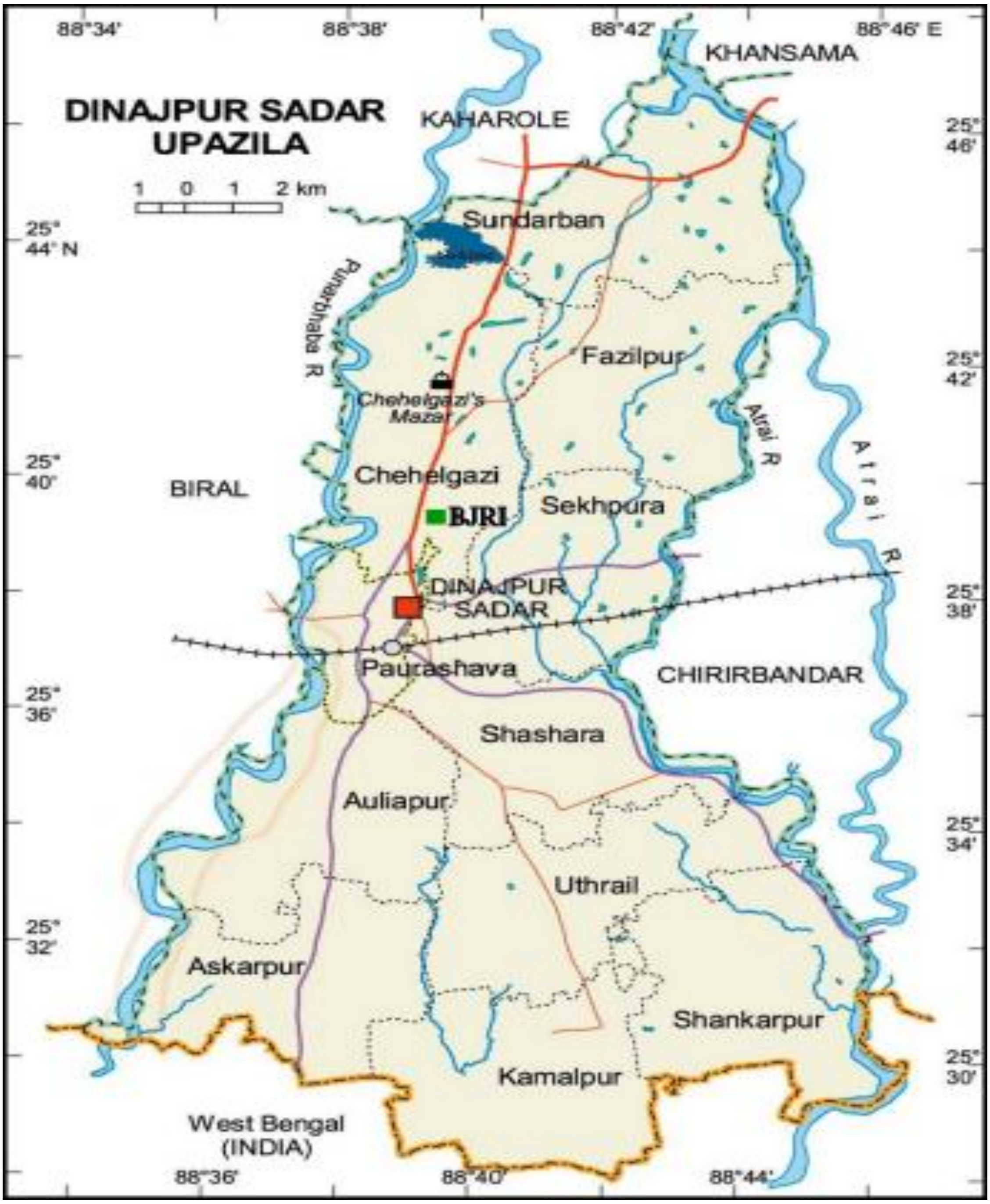
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot).



Appendix II. The monthly mean air temperature, relative humidity and cumulative rainfall recorded at the experimental site during July to December 2024

Months	Relative humidity (%)	Maximum temperature (ºC)	Minimum temperature (ºC)	Rainfall (mm)
July	84	32	27	427
August	84	33	27	413
September	85	32	26	334
October	82	31	23	133
November	76	29	19	2
December	77	26	15	3

Source: BWMRI Metrological Station

Appendix III. Analysis of variance (ANOVA) of plant height at different days after sowing (DAS) of aromatic rice under the effects of variety and different weed management

Source of variation	Degree of freedom	Mean of square			
		Plant height (cm)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	2.166	1.732	1007.53	8.57
Variety (A)	1	6.000^{NS}	135.375**	110.08**	313.93**
Weed management (B)	3	2.833^{NS}	53.233**	202.55**	1110.85**
Interaction (A×B)	3	1.111^{NS}	3.713*	1.95*	2.01*
Error	14	1.976	4.966	10.25	15.79

* = Significant at 5% level, ** = Significant at 1% level and NS= non-significant

Appendix IV. Analysis of variance (ANOVA) of number of tillers $hill^{-1}$ at different days after sowing (DAS) of aromatic rice under the effects of variety and different weed management

Source of variation	Degree of freedom	Mean of square		
		Number of tillers $hill^{-1}$		
		30 DAS	60 DAS	90 DAS
Replication	2	0.792	2.513	2.727
Variety (A)	1	7.935*	1.260^{NS}	5.831*
Weed management (B)	3	2.832^{NS}	3.327^{NS}	8.487**
Interaction (A×B)	3	1.642^{NS}	3.080^{NS}	0.716**
Error	14	1.480	1.758	4.381

* = Significant at 5% level, ** = Significant at 1% level and NS= non-significant

Appendix V. Analysis of variance (ANOVA) of yield traits of aromatic rice under the effects of variety and weed management

Source of variation	Degree of freedom	Mean of square			
		Number effective of tillers $hill^{-1}$	Number non-effective of tillers $hill^{-1}$	Panicle length (cm)	Number of grains $panicle^{-1}$
Replication	2	1.383	1.458	8.501	324.184
Variety (A)	1	44.991**	0.944^{NS}	27.413**	138.432^{NS}
Weed management (B)	3	188.535**	42.755**	108.360**	242.940^{NS}
Interaction (A×B)	3	0.987*	1.749**	2.957*	104.932^{NS}
Error	14	3.391	1.784	1.088	134.257

* = Significant at 5% level, ** = Significant at 1% level and NS= non-significant

Appendix VI. Analysis of variance (ANOVA) of yield characters of aromatic rice under the effects of variety and weed management

Source of variation	Degree of freedom	Mean of square		
		Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	1000-grain weight
Replication	2	702.60	72.429	0.054
Variety (A)	1	119.66*	0.683**	8.484**
Weed management (B)	3	1078.04**	307.962**	9.180**
Interaction (A×B)	3	116.18^{NS}	0.660*	0.194*
Error	14	93.6	11.646	0.182

* = Significant at 5% level, ** = Significant at 1% level and NS= non-significant

Appendix VII. Analysis of variance (ANOVA) of yield characters of aromatic rice under the effects of variety and weed management

Source of variation	Degree of freedom	Mean of square			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.091	1.139	1.675	10.908
Variety (A)	1	0.745**	0.792**	3.074**	39.872**
Weed management (B)	3	1.949**	0.852**	5.356**	148.728**
Interaction (A×B)	3	0.017**	0.693**	0.861**	0.892*
Error	14	0.021	0.063	0.146	2.222

* = Significant at 5% level, ** = Significant at 1% level and NS= non-significant

Appendix VII: Some photos of my research work

Fig. Transplantation of seedlings

Fig. Pre-emergence herbicide application

Fig. Collection of Data

Fig. Harvesting of rice plant

Fig. Threshing of rice plant

Fig. Measuring of grain yield and straw yield

Fig. Various data collection