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# Different harvesting dates influence the growth, seed yield and quality of two rice varieties in Ghana

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**ABSTRACT**

Rice (*Oryza sativa* L.) is a staple food which contains a high amount of nutrients essential for human nutrition, energy supply, and food security. Despite its nutritional value, it does not reach its physiological maturity at the same time thereby affecting the quality of seeds produced when harvested. The overarching objective of this research was to determine the influence of harvesting days on seed yield and quality of two rice varieties (Jasmine 85 and Amankwatia) at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Ghana. A 2 x 3 factorial arranged in a Randomized Complete Block Design with three replications was the study design. Factor one was the two varieties (Jasmine and Amankwatia) and factors two was different harvesting times at three levels [105, 112 and 126 days after transplanting (DAT)]. The study revealed that Jasmine 85 had the highest plant height, number of panicles and number of tillers. The study also showed that the interaction of the varieties and different harvesting times had a significant influence on the germination percentage, germination energy, germination rate index and mean germination time. The study showed that Amankwatia harvested at 126 DAT and Jasmine harvested at 112 DAT respectively performed the best in terms of yield. Furthermore, Amankwatia harvested at 112 DAT and Jasmine harvested at 105 DAT respectively also improved germination parameters. Harvesting of both varieties (Jasmine and Amankwatia) at 112 DAT and 126 DAT will maximize yield while harvesting at Amankwatia at 112 DAT and Jasmine at 105 will improve germination.

**Keywords:** Seed filling, Physiological maturity, Vigour, Emergence and Yield

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## Introduction

More than half of the population of the world depends on rice (*Oryza sativa* L.), which is the second most extensively grown crop (Shrestha *et al.*, 2020). Food security, energy supply, and human nutrition all depend on rice production (Zhu *et al.*, 2022). In addition to vitamins, minerals, riboflavin, niacin, tocopherol, calcium, and other salts, rice is a good source of protein, lipids, carbs, and crude fibre (Verma and Srivastav, 2017; Fresco, 2005). An estimated 162.06 million hectares, or more than 100 countries, are planted with rice per year, yielding 495.78 million tonnes of milled rice and 715 million tonnes of paddy rice (FAOSTAT, 2020). Small farms are typically used to produce the crop in sub-Saharan Africa and Asia which stretches between 0.5 and 3.0 hectare while the USA, Australia and South American countries, use larger farms, at about 2–3 thousand acres (Rao *et al.*, 2017).

Despite the nutritional value of rice, it does not reach its physiological maturity at the same time affecting the quality of seeds produced when harvested. This phenomenon may lead to early and premature seeds being harvested and yield losses due to pest infestations or adverse environmental conditions (Hossain *et al.*, 2009). It is, therefore, crucial to identify the appropriate time of harvesting to increase the yield of seeds and the resultant quality.

Few research works have been conducted on the role of different harvesting days on the seed yield and quality of rice (Aamer *et al.*, 2021; Zhu *et al.*, 2022). Additionally, the influence of different harvesting days on the yield and quality of seeds of Jasmine 85 and Amankwatia are yet to be reported on. One of the key elements influencing seed vigour is harvesting time. There are four distinct phases in the ripening process of rice seeds: the milk, yellow, wax, and dry ripening stages. Farmers usually harvest seeds at the dry ripening stage (Wang *et al.*, 2018). According to Hossain *et al.* (2009), early harvesting could result in more immature and unfilled seeds. These premature seeds may lead to partially chalky kernels and milk-white kernels and increase the thickness of the bran and aleuronic layers. Delaying harvesting increases the possibility of yield losses from pest infestation or adverse weather conditions (Iqbal, 2020). Consequently, it is imperative to the influence of different harvesting days on the yield and quality of seeds from the two rice varieties specifically Jasmine and Amankwatia grown by most farmers in Ghana. The specific objectives of this study were; (i) to evaluate the vegetative growth characteristics of Jasmine and Amankwatia. (ii) to determine the influence of different harvesting times on seed yield and germination performance of Jasmine and Amankwatia.

## Materials and Methods

### *Experimental site*

This experiment was conducted the Kwame Nkrumah University of Science and Technology's Department of Horticulture, Kumasi. The experiment took place between 10th July and 16$^{th}$ December 2023.

### *Source of materials*

Seeds of the two rice varieties were obtained from the Crop Research Institute, Fumesua, Kumasi. Plastic basins were also obtained to aid in planting. Ferric Acrisol type of soil was also collected from the experimental site to aid in planting.

### *Experimental design and procedure*

A 2 x 3 factorial arranged in a Randomized Complete Block Design with three replications was the study design used.

Factor 1 = varieties at two levels (Jasmine and Amankwatia).

Factor 2 = different harvesting times at three levels (105 DAT, 112 DAT and 126 DAT)

### *Seed nursing and transplanting*

The nursery was operated in the Department of Horticulture's plant house using seed trays. Well-decomposed cocopeat was used to fill the seed trays. The seeds were sown at the rate of one seed per tray hole. The seeds were slightly covered with the rice husk and watered regularly. The seedlings were transplanted into buckets 4 weeks after emergence. There were eight buckets per treatment. This was done on the 11$^{th}$ of August, 2023.

### *Preparation of plastic basins before transplanting*

To get rid of broken glasses, plastic, and plant debris, topsoil obtained from the Department was sieved. After the soil had been sieved, it was placed in a metal container tray and sterilized at 100$^{o}$C for 30 minutes. After that, the soil was disinfected, spread out on a sizable sheet, covered, and allowed to cool overnight. 21.3 kg of the sterilized soil was placed into equal-sized plastic basins and allowed to cool. After that, the soil was thoroughly watered to give it time to settle before transplanting. The rice seedlings were transplanted and watered. To improve soil aeration, the soil was stirred twice a week using a hand fork. Again, each basin had holes made in it to allow water to drain.

### *Cultural practices*

Irrigation was done early in the morning and late in the evening using a watering can. Weed infestation and severity were taken into consideration, 2 weeks after transplanting for all the treatments. Hand-picking was done regularly to reduce weed severity. The pesticide was employed through spraying to control pest attacks and disease infestations. Mostly, pests such as snails and rice gall midge were the major crop pests that happened to attack the rice. Compound fertilizer (NPK 15-15-15) was administered to the seedlings at a dosage of 8 g per plant 3 weeks after transplanting. Harvesting was carried out with a knife which was used to cut the panicles. The harvesting was carried out at three different times. The first harvesting was done at 105 days after harvesting, the second harvesting at 112 days after harvesting and the third harvesting at 126 days after harvesting.

### *Data collection*

The following parameters were collected:

#### Growth parameters

i. Height of plants (cm): using a tape measure the height of the rice plants was measured from the base of the plant (at soil level) to the apex and recorded.
ii. Tiller Numbers: tiller numbers were counted on the plants and recorded.
iii. Panicle numbers: panicle numbers were counted and recorded every week after rice panicle initiation.
iv. Seed yield: the yield of the treatments was weighed and recorded.

#### Seed germination parameters

*Seed germination percentage*

The germination test was performed using one hundred (100) seeds from the pure seed fraction of each treatment. A counting board was used to arrange the seeds in three replications of 100 each. Each replicate was then placed in a perforated container with a leveled layer of wet river sand. The first germination count was carried out on the 4th day. On the 7th day seedlings in each replicate were counted and grouped into normal, abnormal, fresh ungerminated and dead seeds. Germination was indicated by the proportion of seeds that had produced normal seedlings under the conditions and within the seventh-day period (ISTA, 2007).

The germination percentage was calculated using the following formula:

Germination Percentage= number of seeds germinated after seven days / total number of seeds tested x 100

*Seedling vigour index*

One week after germination, 10 seedlings' shoot and root lengths were measured for each of the three replicates using the meter rule, and the average was calculated. The vigour index was calculated using the formula of Abdul-Baki and Anderson (1973) as follows:

Vigour Index = (Average Shoot length + Average Root length) x Germination Percentage

*Germination energy*

This was calculated as the number of seeds germinated after four days or seven days or fourteen days divided by the total number of seeds tested multiplied by 100.

*Germination rate index*

This was calculated as a summation of the number of seeds germinated on each day divided by the day starting from the beginning.

*Mean germination time*

This was calculated as the number of seeds germinated on each day multiplied by that particular day, summed together and divided by the total number of seeds germinated at the termination of the experiment.

*Biomass*

The weight of fresh and dry biomass was weighed on a scale and recorded.

### *Analysis of data*

The collected data were subjected to Analysis of Variance (ANOVA) using Statistix Software version 10.0. Differences between treatment means were separated using Tukey's Honestly Significantly Difference (HSD) at a 5% probability level. Figures and tables were used to present the results.

## Results

### *Plant height of the two rice cultivars*

There was a significant difference between the two rice varieties for plant height (Fig. 1). The highest plant height (122.50 cm) was recorded by the Jasmine 85 rice variety while the least plant height (109.50 cm) was recorded by the Amankwatia rice variety.

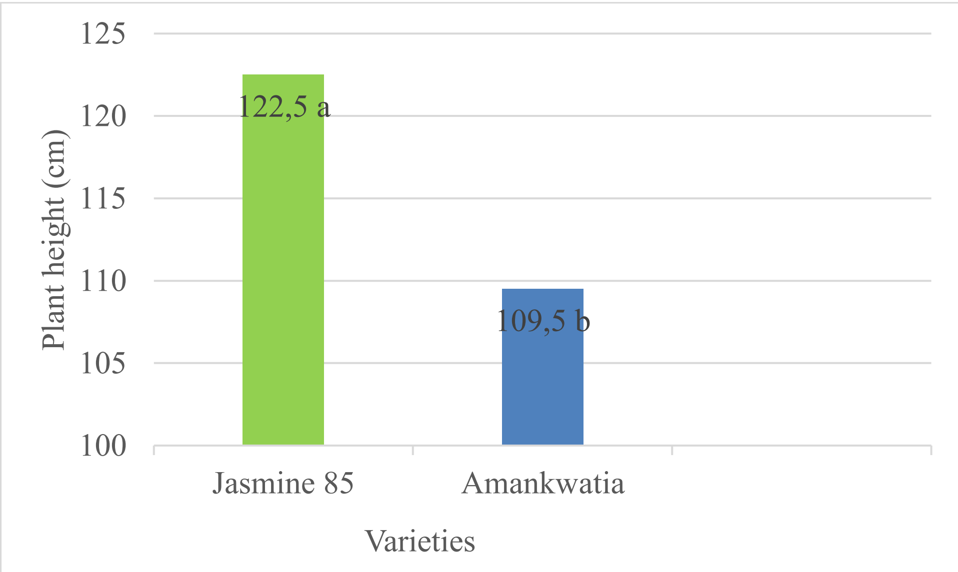


Fig. 1. Plant height (cm) of the two rice cultivars.

### *Tiller numbers of the two rice cultivars*

There was a significant difference between the two rice varieties for the number of tillers (Fig. 2). The highest number of tillers (32.75) was recorded by the Jasmine 85 rice variety and the least tiller numbers (27.88) was recorded by the Amankwatia rice variety.

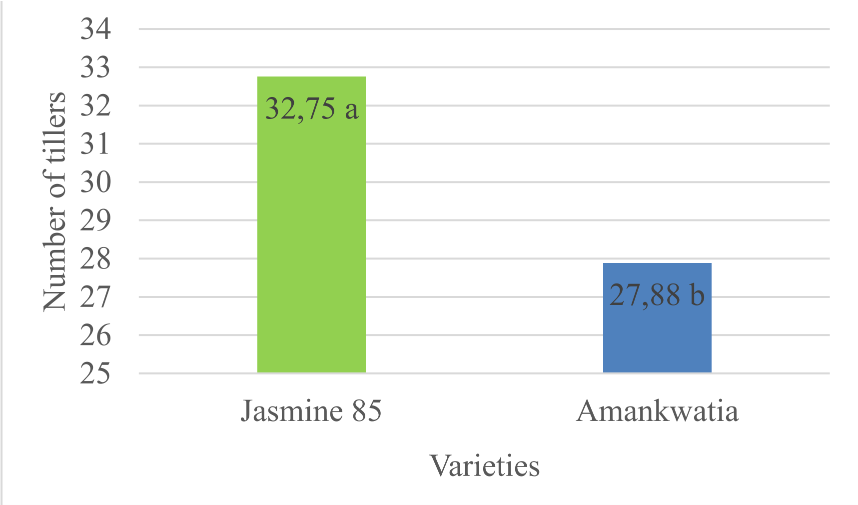


Fig. 2. Tiller numbers of the two rice cultivars.

***Panicle numbers at 84 DAT of two rice cultivars***

There was a significant difference between the two rice varieties for the number of panicles at 84 days after transplanting (Fig. 3). The highest panicle numbers at 84 DAT (4.5) were recorded by Jasmine 85 rice variety. The least panicle numbers at 84 DAT (1.78) were recorded by Amankwatia rice variety.

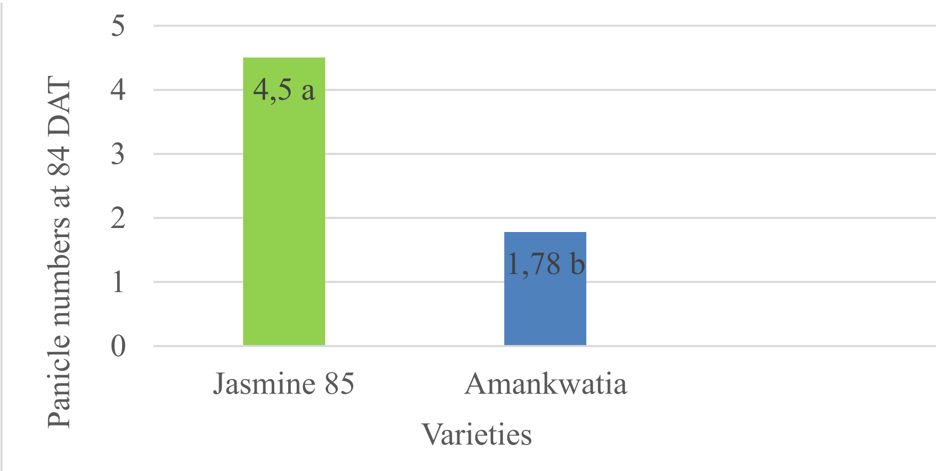


Fig. 3. Panicle numbers at 84 DAT of two rice cultivars.

***Panicle numbers at 91 DAT of two rice cultivars***

There was a significant difference between the two rice varieties for the number of panicles at 91 DAT (Fig. 4). The highest panicle numbers at 91 DAT (18.63) were recorded by Jasmine 85 rice variety. The least panicle numbers at 91 DAT (15.50) were recorded by the Amankwatia rice variety.

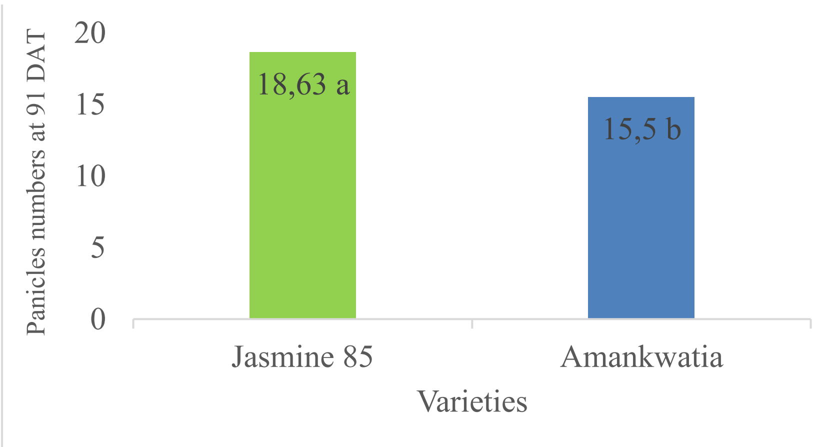


Fig. 4. Panicle numbers at 91 DAT of two rice cultivars.

***Effect of varieties on panicles numbers at 98 DAT of two rice cultivars***

There was a significant difference between the two rice varieties for the number of panicles at 98 DAT (Fig. 5). The highest panicle number at 98 DAT (22.63) was recorded by Jasmine 85 rice variety. The least panicle numbers at 98 DAT (20.75) were recorded by Amankwatia.

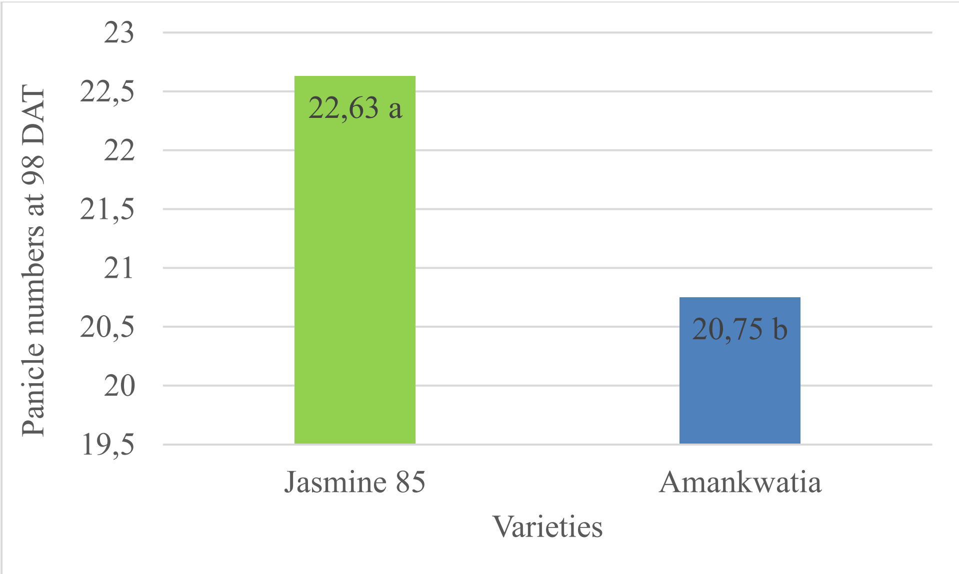


Fig. 5. Panicle numbers at 98 DAT of two rice cultivars.

***Effect of varieties on panicle numbers at 105 DAT of two rice cultivars***

There was no significant difference between the two rice varieties for the number of panicles at 105 DAT (Fig. 6).

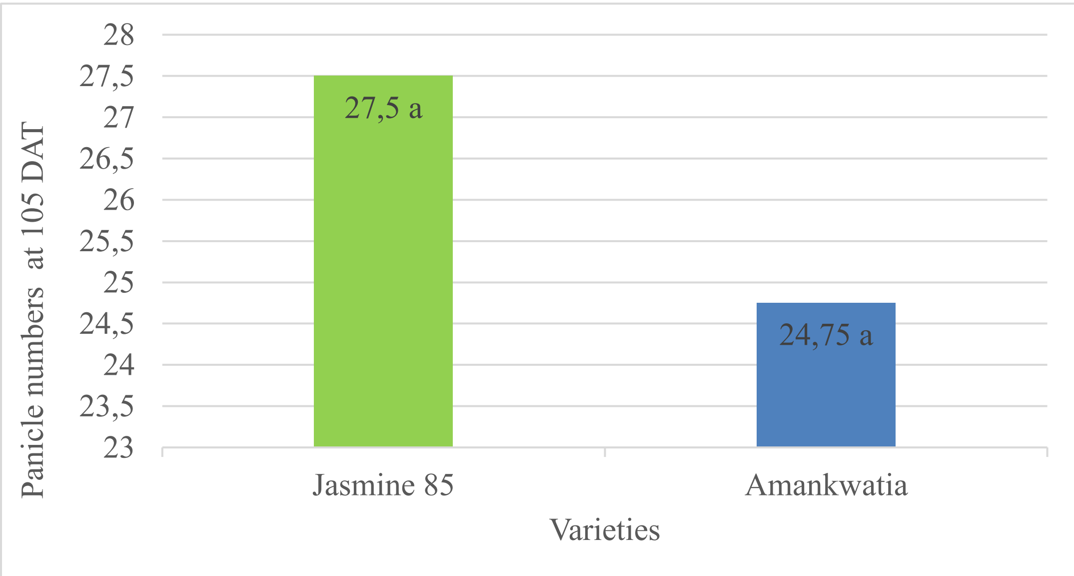


Fig. 6. Panicle numbers at 105 DAT of two rice cultivars.

***Effect of harvesting days and varieties on the yield (kg/m²) of two rice cultivars***

There was a significant difference between the interaction of varieties and harvesting days for seed yield (Table 1). The highest yield (0.14 kg/m²) was recorded by Amankwatia rice variety which was harvested at 126 days after transplanting (DAT). The lowest yield (0.01 kg/m²) was recorded by the Amankwatia rice variety which was harvested at 112 DAT. Considering the varieties only, Jasmine 85 recorded the highest yield and the least was Amankwatia. For the harvesting dates only, seeds harvested at 126 DAT recorded the highest yield and the least was the seeds harvested at 105 DAT.

Table 1. Effect of harvesting days and varieties on yield of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 0.07$^{c}$ | 0.12$^{ab}$ | 0.09$^{bc}$ | 0.09$^{a}$ | |
| Amankwatia | 0.06$^{c}$ | 0.01$^{d}$ | 0.14$^{a}$ | 0.07$^{b}$ | |
| Means | 0.065$^{b}$ | 0.065$^{b}$ | 0.115$^{a}$ | | |
| HSD (5%): Varieties=0.013, Harvesting days=0.020, Varieties x Harvesting days=0.037 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on Germination Percentage (GP) of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for Germination Percentage (GP). The highest GP (100%) was recorded by the Amankwatia rice variety which was harvested at 112 days after transplanting (DAT). The lowest GP (69.50%) was recorded by Jasmine 85 rice variety which was harvested at 126 DAT. Considering the varieties only, Amankwantia recorded the highest GP and the lowest was Jasmine 85. For the Harvesting dates only, seeds harvested at 105 DAT recorded the highest GP and the lowest was those harvested at 126 DAT (Table 2).

Table 2. Effect of harvesting days and varieties on Germination Percentage (GP) of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 93.50$^{c}$ | 85.50$^{d}$ | 69.50$^{f}$ | 82.83$^{b}$ | |
| Amankwatia | 98.50$^{b}$ | 100.00$^{a}$ | 81.50$^{e}$ | 93.33$^{a}$ | |
| Means | 96.00$^{a}$ | 92.75$^{b}$ | 75.50$^{c}$ | | |
| HSD (5%): Varieties=0.428, Harvesting days= 0.665, Varieties x Harvesting days=1.232 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on Germination Energy (GE) of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for Germination Energy (GE). The highest GE (100%) was recorded by Amankwatia rice variety which was harvested at 112 days after transplanting (DAT). The lowest GE (69.50%) was recorded by the Jasmine 85 rice variety which was harvested at 126 DAT. Considering the varieties only, Amankwantia recorded the highest GE and the lowest was Jasmine 85. For the Harvesting dates only, seeds harvested at 105 DAT recorded the highest GE and the lowest was those harvested at 126 DAT (Table 3).

Table 3. Effect of harvesting days and varieties on Germination Energy (GE) of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 93.50$^{c}$ | 85.50$^{d}$ | 69.50$^{f}$ | 82.83$^{b}$ | |
| Amankwatia | 98.50$^{b}$ | 100.00$^{a}$ | 81.50$^{e}$ | 93.33$^{a}$ | |
| Means | 96.00$^{a}$ | 92.75$^{b}$ | 75.50$^{c}$ | | |
| HSD (5%): Varieties=0.428, Harvesting days= 0.665, Varieties x Harvesting days=1.232 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on Germination Rate Index (GRI) of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for the Germination Rate Index (GRI). The highest GRI (68.91) was recorded by Amankwatia rice variety which was harvested at 105 days after transplanting (DAT). The least GRI (38.67) was recorded by Jasmine 85 rice variety which was harvested at 126 DAT. Considering the varieties only, Amankwantia recorded the highest GRI and the lowest was Jasmine 85. For the Harvesting dates only, seeds harvested at 105 DAT recorded the highest GRI and the lowest was those harvested at 126 DAT (Table 4)

Table 4. Effect of harvesting days and varieties on Germination Rate Index (GRI) of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 54.53$^{c}$ | 50.66$^{d}$ | 38.67$^{f}$ | 47.95$^{b}$ | |
| Amankwatia | 68.91$^{a}$ | 65.75$^{b}$ | 45.48$^{e}$ | 60.05$^{a}$ | |
| Means | 61.72$^{a}$ | 58.21$^{b}$ | 42.08$^{c}$ | | |
| HSD (5%): Varieties=0.064, Harvesting days=0.100, Varieties x Harvesting days=0.185 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on Mean Germination Time (MGI) of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for Mean Germination Time (MGT). The highest MGT (21.01 days) was recorded by Amankwatia rice variety which was harvested at 105 days after transplanting (DAT). The least MGT (17.71 days) was recorded by Jasmine 85 rice variety which was harvested at 126 DAT. Considering the varieties only, Amankwatia recorded the highest MGT and the lowest was Jasmine 85. For the harvesting days only, seeds harvested at 105 DAT recorded the highest MGT and the least was seeds harvested at 126 DAT (Table 5)

Table 5. Effect of harvesting days and varieties on Mean Germination Time of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 18.36$^{c}$ | 18.46$^{c}$ | 17.71$^{e}$ | 18.18$^{b}$ | |
| Amankwatia | 21.01$^{a}$ | 20.12$^{b}$ | 17.93$^{d}$ | 19.68$^{a}$ | |
| Means | 19.69$^{a}$ | 19.29$^{b}$ | 17.82$^{c}$ | | |
| HSD (5%): Varieties=0.050, Harvesting days=0.078, Varieties x Harvesting days=0.145 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on the average hypocotyl length of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for average hypocotyl length. The highest average hypocotyl length (17.42 cm) was recorded by Jasmine 85 rice variety which was harvested at 112 days after transplanting (DAT). The least average hypocotyl length (14.81cm) was recorded by Amankwatia rice variety which was harvested at 105 DAT. Considering the varieties only, Jasmine 85 recorded the highest average hypocotyl length and the least was Amankwatia. For the Harvesting dates only, seeds harvested at 112 DAT recorded the highest average hypocotyl length and the lowest were the seeds harvested at 105 DAT (Table 6).

Table 6. Effect of harvesting days and varieties on Average Hypocotyl Length of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 15.72$^{d}$ | 17.42$^{a}$ | 16.25$^{c}$ | 16.46$^{a}$ | |
| Amankwatia | 14.81$^{f}$ | 17.08$^{b}$ | 15.26$^{e}$ | 15.72$^{b}$ | |
| Means | 15.27$^{c}$ | 17.25$^{a}$ | 15.76$^{b}$ | | |
| HSD (5%): Varieties=0.043, Harvesting days=0.067, Varieties x Harvesting days=0.123 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

### *Effect of harvesting days and varieties on the average root length of two rice cultivars*

There was a significant difference between the interaction of varieties and harvesting dates for average root length. The highest average root length (13.36 cm) was recorded by the Jasmine 85 rice variety which was harvested at 112 days after transplanting. The least average root length (4.23 cm) was recorded by the Amankwatia rice variety which was harvested at 112 DAT. Considering the varieties only, Jasmine 85 recorded the highest average root length and the least was Amankwatia. For the Harvesting dates only, seeds harvested at 112 DAT recorded the highest average root length and the least were those harvested at 105 DAT (Table 7).

Table 7. Effect of harvesting days and varieties on Average Root Length of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 12.14$^{b}$ | 13.36$^{a}$ | 4.58$^{c}$ | 10.03$^{a}$ | |
| Amankwatia | 12.41$^{ab}$ | 4.23$^{c}$ | 12.12$^{b}$ | 9.59$^{b}$ | |
| Means | 12.28$^{a}$ | 8.80$^{b}$ | 8.35$^{b}$ | | |
| HSD (5%): Varieties=0.412, Harvesting days=0.625, Varieties x Harvesting days=1.114 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

***Effect of harvesting days and varieties on the Vigour Index of two rice cultivars***

There was a significant difference between the interaction of varieties and harvesting dates for the Vigour Index (VI). The highest VI (2681.7) was recorded by Amankwatia rice variety which was harvested at 105 days after transplanting (DAT). The least VI (1448.2) was recorded by Jasmine 85 rice variety which was harvested at 126 DAT. Considering the varieties only, Amankwantia recorded the highest MGT and the lowest was Jasmine 85. For the Harvesting days only, seeds harvested at 105 DAT recorded the highest MGT and the least was the seeds harvested at 126 DAT (Table 8).

Table 8. Effect of harvesting days and varieties on the Vigour Index of two rice cultivars.

| Harvesting dates | | | | | |
|---|---|---|---|---|---|
| Varieties | 105 DAT | 112 DAT | 126 DAT | Means | |
| Jasmine 85 | 2576.4[b] | 2632.2[ab] | 1448.2[e] | 2219.0[b] | |
| Amankwatia | 2681.7[a] | 2131.0[d] | 2232.0[c] | 2348.2[a] | |
| Means | 2629.1[a] | 2381.6[b] | 1840.1c | | |
| HSD (5%): Varieties= 24.489, Harvesting days=38.014, Varieties x Harvesting days=70.450 | | | | | |

*DAT: Days after transplanting, HSD: Honestly Significant Difference at 1% probability value.*

***Correlation relationship among seed germination parameters***

*Correlation relationship among certain variables*

There was a significant, strong, and positive correlation between Germination Energy and Germination Rate Index (r=0.96), Germination Percentage and Germination Rate Index (r=0.96), Seed Vigour Index and Average Root length (r=0.82), Seed Vigour Index and Germination Percentage (r=0.68), and Mean Germination Time and Germination Energy (0.82). This type of relationship were in line with the report of Wani and Singh (2016), who found that the germination parameters of *Pongamia pinnata* were positively correlated. According to Santana and Ranal (2006), any effect on one germination factor has a corresponding impact on the other germination factors. Having a shorter Mean Germination Time is preferable for a greater Germination Rate Index, as it indicates that seeds can establish themselves faster and more evenly. This is especially crucial to maximizing planting timelines and ensuring quicker crop establishment (Singh *et al.*, 2021).

Table 9. Correlation relationship among certain seed variables.

| Variables | Correlation coefficient (r) | P value (0.01) |
|---|---|---|
| Germination Energy and Germination Rate Index | 0.9564 | 0.0000 |
| Germination Percentage and Germination Rate Index | 0.9564 | 0.000 |
| Seed Vigour Index and Average Root Length | 0.8187 | 0.00011 |
| Seed Vigour Index and Germination Percentage | 0.6836 | 0.0142 |
| Mean Germination Time and Germination Energy | 0.8209 | 0.0011 |

## Discussion

Results of this study indicated that the highest plant height (122.50 cm) was recorded by the Jasmine 85 rice variety and the least plant height (109.50 cm) was recorded by the Amankwatia rice variety. This could be a result of the genetic factors, environmental factors and agricultural practices that affected the two rice varieties. Our results agree with the findings of Khush (2001) who reported that rice cultivars with different genetic backgrounds can have varying plant heights. Teng *et al.* (2004) and Yin *et al.* (2015) also reported that high temperatures and light intensity can increase plant height. Conversely, environmental factors such as excessive water depth, inadequate nutrient supply, especially nitrogen, high plant densities and poor soil drainage and aeration can reduce plant height (Kumar *et al.*, 2017; Pandey *et al.*, 2017; Akhter *et al.*, 2018; Bhattacharyya *et al.*, 2013).

Our results indicated that the highest panicle numbers at 84 DAT, 91 and 98 were recorded by Jasmine 85 rice variety and the least panicle numbers were recorded by Amankwatia rice variety. Similarly, the result indicated that the highest tiller (32.75 cm) was recorded by the Jasmine 85 rice variety and the least plant height (27.88 cm) was recorded by the Amankwatia rice variety. This could be due to the difference in the genetic makeup of the two rice varieties. Khush (2001) reported that rice cultivars with different genetic backgrounds can have varying panicle numbers. However, environmental factors such as excessive water depth, inadequate nutrient supply, especially nitrogen, high plant densities and poor soil drainage and aeration can delay and reduce panicle numbers (Teng *et al.*, 2004; Kumar *et al.*, 2017; Pandey *et al.*, 2017; Akhter *et al.*, 2018; Bhattacharyya *et al.*, 2013).

Our results showed that the highest yield (0.14 kg/m²) was recorded by the Amankwatia rice variety which was harvested at 126 days after transplanting and the least yield (0.01 kg/m²) was recorded by the Amankwatia rice variety which was harvested at 112 DAT. This could be a result of environmental factors and agricultural practices affecting the rice varieties. Our results corroborate with the reports of Gopalakrishnan *et al.* (2019), Rani *et al.* (2020) and Singh *et al.* (2018) who reported that adequate water supply, irrigation, and drainage, optimal temperature (20-35°C), solar radiation, and rainfall patterns, effective control of pests and diseases like blast, brown plant hopper, and sheath blight and balanced fertilization, nutrient uptake, and soil fertility can affect rice yield.

In the current study, our results showed that the highest GP and GE (100%) were recorded by the Amankwatia rice variety which was harvested at 112 days after transplanting (DAT) and the least GP and GE (69.50%) recorded by Jasmine 85 rice variety which was harvested at 126 DAT. This observation could be attributed to the differences in the genetic makeup of the two varieties. The differences in the genetic make-up observed for germination percentage and energy under favourable conditions significantly affect the time required for seedlings to germinate in the field, thereby impacting early vigour and grain yield in drier conditions, particularly in early season drought in rain-fed lowland regions (Fukai and Wade, 2021). Our results corroborate with the reports of Chao *et al.* (2021) who opined on the genotypic differences in eight rice varieties they used for the study. Our results indicated that the highest GRI (68.91) was recorded by the Amankwatia rice variety which was harvested at 105 days after transplanting (DAT) and the lowest GRI (38.67) was recorded by the Jasmine 85 rice variety which was harvested at 126 DAT. This observation could be a result of the influence of genetic factors, seed vigour and age of seeds. Similarly, Rao *et al.* (2018) reported that rice varieties with inherent high GRI potential could exhibit better germination rates. Additionally, Kumar *et al.* (2017) reported that high-vigour seeds exhibit faster and more uniform germination, resulting in a higher GRI. Further, our results agree with the findings of Singh *et al.* (2018) who reported that fresh seeds generally exhibit higher GRI than older seeds. On the contrary, environmental factors such as excessive or insufficient moisture, extreme temperatures (below 15°C or above 40°C), excessive water, and pest and disease infestations can reduce GRI (Srivastava *et al.*, 2016, Gopalakrishnan *et al.*, 2019, Rani *et al.*, 2020).

Our results indicated that the highest MGT (21.01 days) was recorded by Amankwatia rice variety which was harvested at 105 days after transplanting (DAT). The least MGT (17.71 days) was recorded by Jasmine 85 rice variety which was harvested at 126 DAT. This is because of the differences in the genetic makeup of the two varieties, the seed quality and the age of the seed. Our results agree with the findings of Rao *et al.* (2018) who reported that rice varieties with inherent fast germination potential can exhibit lower MGT. Our results also agree with the findings of Kumar *et al.* (2017) who reported that high-quality seeds with good viability and vigour exhibit faster germination, reducing MGT. Furthermore, our results agree with the findings of Singh *et al.* (2018) who reported that fresh seeds generally exhibit faster germination, reducing MGT. However, environmental factors such as extreme temperatures (below 15°C or above 40°C), excessive or insufficient moisture, pests and disease infestations can increase MGT (Srivastava *et al.*, 2016, Rani *et al.*, 2020).

Our results showed that the highest average hypocotyl length (17.42 cm) was recorded by the Jasmine 85 rice variety which was harvested at 112 days after transplanting (DAT). The least average hypocotyl length (14.81 cm) was recorded by Amankwatia rice variety which was harvested at 105 DAT. This could be a result of the influence of genetic and environmental factors on the two rice varieties. Our results agree with the findings of Rao *et al.* (2018) who reported that rice varieties with inherent traits for shoots can exhibit different growth patterns (Rao *et al.*, 2018). Our results also agree with the findings of Kumar *et al.* (2017), Gopalakrishnan *et al.* (2019), and Singh *et al.* (2018) who reported that environmental factors such as light, temperature, water availability, and nutrient availability can affect shoot growth.

Our results indicated that the highest average root length (13.36 cm) was recorded by Jasmine 85 rice variety which was harvested at 112 days after transplanting. The least average root length (4.23 cm) was recorded by the Amankwatia rice variety which was harvested at 112 DAT. This could be a result of the influence of environmental factors on the two rice varieties. Our results agree with the findings of Kumar *et al.* (2017), Gopalakrishnan *et al.* (2019), and Singh *et al.* (2018) who reported that environmental factors such as light, temperature, water availability, and nutrient availability can affect root development.

Our results depicted that the highest Vigour index (2681.7) was recorded by the Amankwatia rice variety which was harvested 105 days after transplanting and the least Vigour index (1448.2) was recorded by the Jasmine 85 rice variety which was harvested at 126 DAT. This could be due to the differences in the genetic constitution of the two rice varieties. Our results agree with the findings of Basu *et al.* (2023) who reported that the vigour differences among seed lots may be due to variability in genotype, environment, and maturity at harvest, mechanical integrity, seed treatments and seed ageing.

## Conclusion

Amankwatia harvested at 126 DAT and Jasmine harvested at 112 DAT respectively performed the best in terms of yield. Amankwatia harvested at 112 DAT and Jasmine harvested at 105 DAT respectively also improved germination. The study also revealed that there was a significant, strong, and positive correlation between Germination Energy and Germination Rate Index (r=0.96), Germination Percentage and Germination Rate Index (r=0.96), Seed Vigour Index and Average Root length (r=0.82), Seed Vigour Index and Germination Percentage (r=0.68), and Mean Germination Time and Germination Energy (0.82).

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