International Journal of Agricultural Technology 2023 Vol. 19(2):609-620
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Harvesting time influences seed germination and vigour of some coloured rice varieties in Thailand

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Rodnuch, N., Aninbon, C. and Kaewtaphan, P. (2023). Harvesting time influences seed germination and vigour of some coloured rice varieties in Thailand. International Journal of Agricultural Technology 19(2):609-620.

Abstract The harvesting time were significantly different for all traits of seedling rice including germination percentage, mean germination time (MGT), fresh weights of shoots and roots, dried of shoots and roots. Rice harvested at 20 days after anthesis had the highest germination percentage, and plant stands in term of fresh and dried weights of roots and shoots in all varieties, and they also had the lowest mean germination time. Rice Berry and Tubtim Chumphae had higher germination percentage after storage for six months than Sang Yod variety. When harvested at 20 days after anthesis, the germination percentages of Rice Berry, Tubtim Chumphae and Song Yod were 98.00, 99.00 and 67.50, respectively.

Keywords: Days after anthesis, Germination percentage, Healthy food, Mean germination time

Introduction

Rice is an important cereal crop in tropical and temperate regions, and it is grown mostly in flood land although upland rice is also cultivated. Thailand is a leading rice exporter, and rice is grown in all parts of the country. Thailand produces and consumes both non glutinous and glutinous rice, and most rice consumed and exported is white rice. The current concern on health problem leads the consumers to look for more health products, and coloured rice receives more attention from the consumers, who are willing to pay higher price. The advantage of coloured rice over white rice is that it had high phytochemicals with antioxidant activity (Aninbon *et al*., 2022; Laokuldilok *et al*., 2011). Coloured rice is a great source of nutritional value and antioxidant properties (Priya *et al*., 2019).

Seed is an important factor affecting rice yield and rice quality. Improvement of rice seed quality is one of the important factors to improve rice productivity and rice quality. Seed germination and seedling vigor are

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important criteria of seed quality, and seed quality is highest when the seed is harvested at physiological maturity (PM) (Trakunpaisan *et al*., 2021; Bareke, 2018).

After physical maturity, the degeneration of the seeds will begin, and the rate of seed degradation depends on the environment. Although the seed harvested at physical maturity has the highest seed quality, the farmers often do not harvest at this stage because the seed moisture is too high. Harvest after seed maturity results in poor seed quality and shortens storage time. Delayed harvesting can also lead to yield losses due to damaging seed ruptures. Shaheb *et al*. (2015) reported that harvest time was an important factor affecting seed quality of French bean.

In rice, harvesting time affected seeds germination percentages. Germination percentage were found to be high when harvested at 20 days after pollination, and it was low when harvested at 15 days after pollination (Fu *et al*., 2017). Wang *et al*. (2018) found that harvesting time influenced seed quality, and suitable harvesting period of hybrid rice was at 17-23 days after anthesis. Moreover, Feyem *et al*. (2017) found that harvesting rice between 30-40 days after 50 percentage of heading obtain good germination rate.

Previous studies indicated that the harvest time had a significant effect on seed quality. However, the appropriated harvest times of coloured rice varieties popularly grown in Thailand have not been clearly investigated. The objective was to evaluate the effects of harvesting time on seed germination and vigour of some coloured rice varieties in Thailand.

Materials and methods

Experimental design

The experiment was conducted in Trat province during August - December 2021. A split plot design with four replications was used. Main plots had three coloured rice varieties including Rice Berry, Tubtim Chumphae and Sang Yod. These varieties are popular among the consumers. Subplots consisted of four harvesting dates including 15, 20, 25 and 30 days after anthesis (DAA). The crop was transplanted in the plots with the plot size of 2×3 meters and the spacing of 50×25 cm and the total was 48 plots.

Agricultural practice

The soil was ploughed twice for weed control and left follow until transplanting. Before transplanting, the soil was ploughed again and puddled.

The seedlings of all varieties with 25-day old were transplanted at the rate of 1 plant per hill. Chemical fertilizer 16-20-0 at the rate of 156.25 kg ha^{-1} was applied at 20 days after transplanting (DAP), and urea (46-0-0) was applied at the rate of 62.5 kg ha^{-1} at pre-heading stage.

Data collection

After harvest, seeds were kept in cool room (4 ℃) for six months and germination percentage and vigour were analysed. Twenty-five seeds of each subplot were geminated by top of paper method at room temperature. Germination percentage was assessed at 7 days of age by counting normal seedling (ISTA, 2013). Mean germination time (MGT) of seedlings were normally counted for 7 days. The data were used to calculate the mean germination time as follows (Ellis and Roberts, 1980);

MGT = (G1D1) + (G2D2) (G3D3) +…+ (GnDn) / Total normal seedling,

Where G 1, 2, …n is number of normal seedlings with germinate at date 1, 2, …n (=7) and D 1, 2, …n is number of days D 1, 2, …n counted after the day of sowing.

After counting, seven days age seedling of each plate were separated into shoot and root parts. The samples were weighted to get shoot fresh weight (SFW) and root fresh weight (RFW). After that shoot and root sample were oven dried at 70 ℃ for 48 h to get shoot dry weight (SDW) and root dry weight (RDW).

Data analysis

Data were analysed according to a split plot design using MSTAT-C program (Bricker, 1989), and Duncan's multiple rang test (DMRT) was compared the means at probability level of 0.05. Correlation among traits was calculated on plot data using Microsoft Excel.

Results

Varieties were significantly different ($P \leq 0.05$) for all traits including germination percentage, mean germination time, shoot fresh weight, root fresh weight, shoot dry weight and root dry weight and harvesting times were also significantly different ($P \leq 0.05$ and 0.01) for all traits (Table 1). The interactions

between variety and harvesting time were significant (P≤0.05 and 0.01) for all traits except shoot fresh weight.

Table 1. Mean squares for germination percentage, mean germination time (MGT), root fresh weight (RFW), shoot fresh weight (SFW), root dry weight (RDW) and shoot dry weight (SDW) of three rice varieties harvested at different times

SOV	df	Germination percentage	MGT	RFW	SFW	RDW	SDW
Replication	3	43.89	0.33	0.00007	0.00014	0.00010	0.00004
Variety (A)	2	18,402.33**	1.54**	0.01106**	0.02420**	0.00375**	0.00429**
Error (a)	6	27.22	0.02	0.00007	0.00050	0.00005	0.00002
DAA (B)	3	1,333.66**	1.28**	0.00179**	0.00742**	0.00067**	0.00083**
A x B	6	642.33**	0.37**	0.00058**	0.00008^{ns}	0.00021**	0.00018*
Error (b)	27	95.29	0.04	0.00011	0.00057	0.00001	0.00005
CV (%)		13.27	5.35	23.70	29.45	13.02	20.23

DAA = Days after anthesis, ns, *, **= not significant and significant at 0.05 and 0.01 probability levels, respectively

Germination of three rice varieties was presented in Figure 1. Germination percentage was evaluated at 15, 20, 25 and 30 DAA. Harvesting times were significantly different ($P \leq 0.05$) for germination percentage in all rice varieties (Figure 2). In Riceberry, harvest at 15 DAA was lowest (74%), and it was significantly lower than harvest times at 20, 25 and 30 DAA, which were similar and had the germination percentages of 98.00, 95.00 and 97.00%, respectively.

In Tubtim Chumphae, harvest at 15 DAA was also lowest (90.56%), and it was significantly lower than harvest times at 20 and 30 DAA, which had germination percentages of 99.00 and 98.00%, respectively. However, it was similar to harvest at 25 DAA, which had germination percentage of 94.00%.

In Song Yod, harvest at 20 DAA had shown the highest germination parentage of 67.50%, which was significantly higher than harvest times at 15 DAA (28.73%), and 30 DAA (30.00%), which were similar. It is interesting to note here that Sang Yod had very poor germination percentages, which were lower than commercial standard (80.00%).

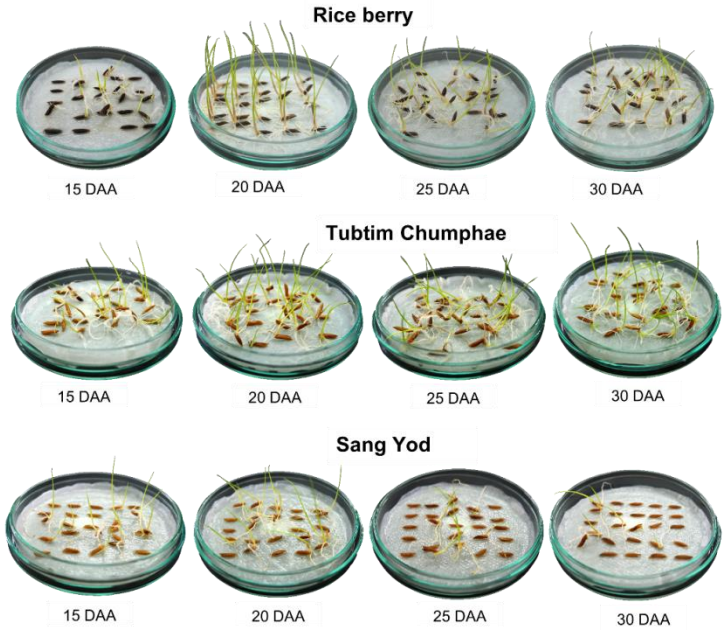

Figure 1. Germination of three rice seedling varieties harvested at 15, 20, 25 and 30 days after anthesis (DAA)

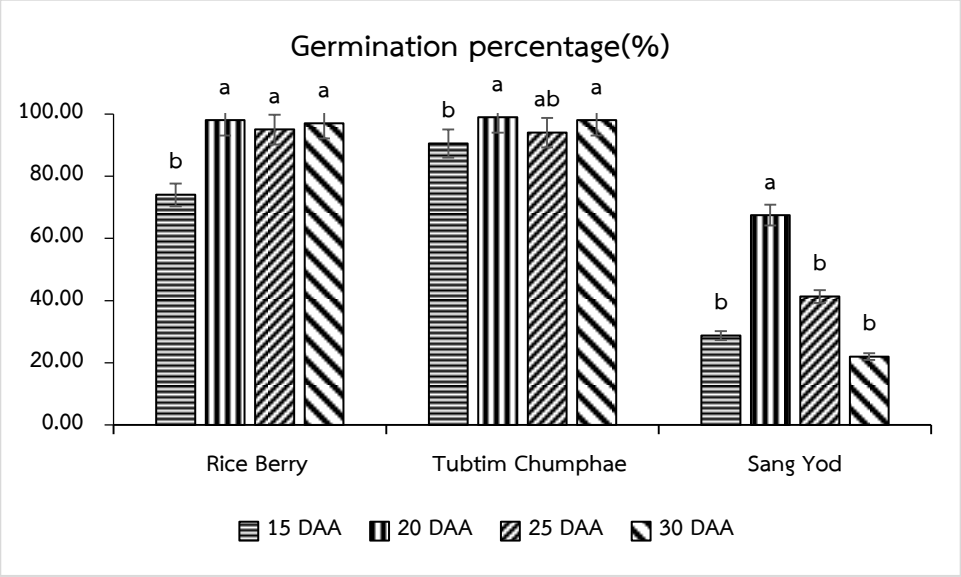

Figure 2. Germination percentage (%) of three rice varieties harvested at 15, 20, 25 and 30 days after anthesis (DAA)

Harvesting times were significantly differed (P≤0.05) for MGT in Rice Berry and Tubtim Chumphae, but they were not significantly different in Sang Yod (Figure 3). In Rice Berry, harvest at 15 DAA had the highest MGT of 4.45 days followed by harvest at 25 DAA (4.05 days), whereas harvest at 20 DAA had the lowest MGT of 3.38 days.

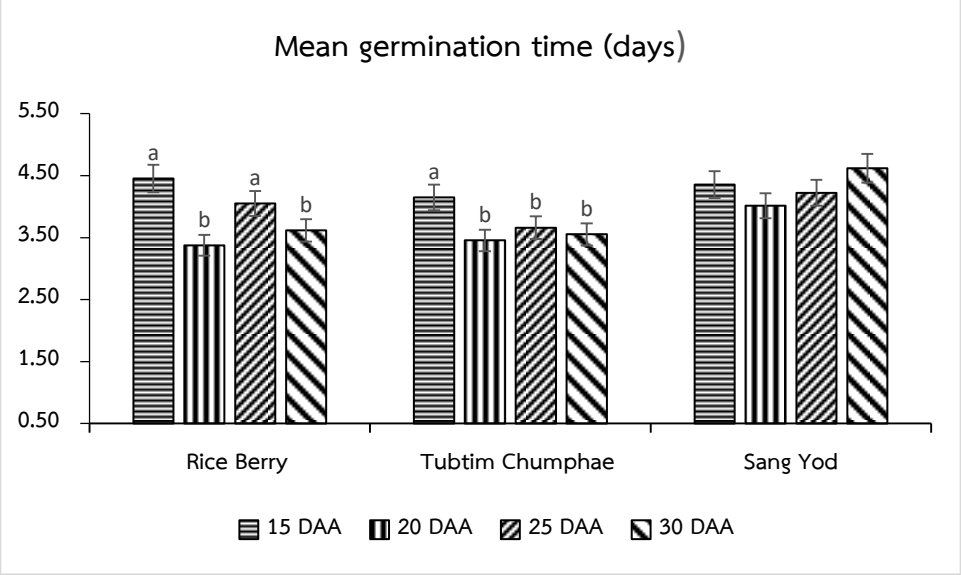

Figure 3. Mean germination times (days) of three rice varieties harvested at 15, 20, 25 and 30 days after anthesis (DAA)

In Tubtim Chumphae, harvest at 15 DAA also had shown the highest MGT of 4.15 days, and it was significantly higher than harvesting at 20, 25 and 30 DAA, which had similar resulted in MGT values of 3.46, 3.66 and 3.55 days, respectively.

In Sang Yod, MGT values ranging from 4.02 to 4.62 days were not significantly different among harvesting times. However, the harvesting time at 20 DAA tended to be lowest MGT value (4.02 days).

In Rice Berry, harvesting dates were significantly differed *(P*≤0.05) for root fresh weight, root dry weight and shoot dry weight, but they were not significantly different for shoot fresh weight (Table 3). The harvesting at 20 DAA had the highest root fresh weight, shoot fresh weight, root dry weight and shoot dry weight, whereas harvest at 15 DAA had the lowest root fresh weight, root dry weight and shoot dry weight.

Table 2. Means for root fresh weight, shoot fresh weight, root dry weight and shoot dry weight of rice seedlings of three rice varieties harvested at 15, 20, 25 and 30 days after anthesis (DAA)

Variety	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)
Rice Berry				
15 DAA	0.029^{c}	0.090	0.023^{c}	0.025^{c}
20 DAA	0.081^{a}	0.133	0.052^{a}	0.058^{a}
25 DAA	0.061^{b}	0.087	0.038^{b}	0.043^{b}
30 DAA	0.080^{ab}	0.071	0.047^{c}	0.052^{a}
Tubtim Chumphae				
15 DAA	0.042	0.095^{b}	0.032	0.035
20 DAA	0.055	0.147^{a}	0.039	0.053
25 DAA	0.051	0.102^{b}	0.036	0.047
30 DAA	0.067	0.099^{b}	0.034	0.045
Sang Yod				
15 DAA	0.011^{bc}	0.027^{b}	0.007^{c}	0.014^{c}
20 DAA	0.030^{a}	0.071^{a}	0.022^{a}	0.031^{a}
25 DAA	0.015^{b}	0.024^{b}	0.015^{b}	0.022^{b}
30 DAA	0.006^{c}	0.012^{c}	0.004^{c}	0.007^{d}

Means in the same column and the same variety with the same letter(s) are not significantly different by DMRT at $P \leq 0.05$.

Table 3. Correlation coefficients (r) of germination and seed vigor traits of rice varieties harvested at 15, 20, 25 and 30 days after anthesis (DAA)

Variable	Germination	MGT	RFW	SFW	RDW
MGT	-0.668**				
RFW	0.744**	-0.679**			
SFW	0.672**	-0.601**	0.699**		
RDW	0.551**	-0.611**	0.783**	0.556**	
SDW	0.870**	-0.729**	0.829**	0.721**	0.714**

**= significant at 0.01 probability level, n = 48

MGT=mean germination time, RFW = root fresh weight, SFW = shoot fresh weight, RDW = root dry weight and SDW = shoot dry weight

In Tubtim Chumphae, significant differences *(*$P \leq 0.05$) among harvesting dates were observed for shoot fresh weight only. Although harvesting times were not significantly different for other traits, the patterns were similar for all traits. Harvest at 20 DAA was highest for all traits, whereas harvest at 15 DAA was lowest for all traits.

In Sang Yod, harvesting times, were significantly differed ($P \leq 0.05$) for all traits, and harvesting at 20 DAA was shown the highest for all traits. However, harvest at 30 DAA was found the lowest for all traits.

Mean germination time was negatively correlated with germination percentage, root fresh weight, shoot fresh weight, root dry weight and shoot dry

weight, and the correlation coefficients (r) ranged from -0.601 to -0.729 (Table 3). However, germination percentage, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight were intercorrelated, and the correlation coefficients (r) ranged between 0.551 and 0.870.

Discussion

Significant differences among rice varieties and harvesting times for traits related to seed quality indicated that the varieties with high seed quality and the harvesting times, that provided good seed quality, could be identified. According to Ranmeechai *et al*. (2022), rice genotype had interactions with other factors such as hydropriming duration, and storage time that affected seed germination and seed vigour. Weak interactions may not cause a problem. However, the strong and significant interactions between variety and harvesting time would be problematic in the selection.

In this study, harvesting at 20 DAA provided the highest germination percentages in all rice varieties. Harvesting at 15 DAA had the lowest germination percentage in all varieties, whereas harvesting at 30 DAA had the lowest germination percentage in Sang Yod only, and Sang Yod also had the lowest germination percentages at all harvesting times compared to Rice Berry and Tubtim Chumphae.

Rice harvesting at 15 DAA may not be able to fully accumulate dry weight (immaturity seeds), and the germination rate of seed was reduced. Rice Berry and Tubtim Chumphae could be harvested at 20 to 30 DAA without severe reduction in germination percentage. According to Fu *et al*. (2017), rice harvesting at 20 DAA had shown to be higher germination percentage than the crop harvested at 15 DAA. However, Baktiar *et al*. (2013) found that rice harvested at 30 DAA had the highest filled grain and germination percentage, and they concluded that harvesting at 30 to 35 DAA was suitable for obtaining high seed quality. The differences in the results from different studies would be due to different varieties. Cultivar differences were evident for germination rate following aging and under low temperature (20 and 15 ℃) and moisture stress (Krishnasamy and Seshu, 1989). In this study, Sang Yod was resulted to be different from Rice Berry and Tubtim Chumphae.

Mean germination times were found to be lowest at 20 DAA in all rice varieties, indicating that the seed harvesting time had shown to be the most rapid germination. It was found to be the most suitable to harvesting rice at 20 DAA which obtained the highest seed quality. However, for Rice Berry and Tubtim Chumphae, the seed harvesting at 30 DAA also had shown to be low

mean germination times, and it is recommended to harvest at 30 DAA, if good drying facility is not available.

Rapid germination is a criterion determining seed quality as it supports rapid establishment of the crop and better competition with weeds. In general, seed vigour is influenced by maturity stage in harvesting time (Ghassemi and Hosseinzadeh, 2009; Fu *et al*., 2017). According to Talei *et al.* (2013), rice seed exposed to 2450 MHz of microwave frequency for ten hours could increase germination percentage to 100%, and the MGT value was 2.1 days. Adachi *et al*. (2015) found that MGT values were in a range between 2.3 and 3.2 days. In this study, MGT values ranged between 3.38 and 4.62. High MGT values in this study would be due to long storage for six months.

Most rice varieties had shown to be the highest root fresh weight, shoot fresh weight, root dry weight and shoot dry weight at 20 DAA except Tubtim Chumphae, which had the highest root fresh weight at 30 DAA. The results indicated that harvesting at 20 DAA was found to be the most suitable for seed production.

Root weight and shoot weight are indicators for the parameters determining seedling vigour and initial establishment of rice (Xu *et al*., 2019). High root weights in rice harvesting at 20 DAA would be due to longer grain filling duration that allowed the crop to reach physiological maturity (Wang *et al*., 2020).

In this study, mean germination time was negatively associated with germination percentage, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight. The results indicated that the varieties and harvesting times with the lowest mean germination time should be selected for seed production. Germination percentage, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight were positively associated, indicating their usefulness for evaluation of seed quality.

Rice Berry and Tubtim Chumpae had similar seed quality and suitable for seed production, whereas Sang Yod had poor seed quality and should be delated from seed production plan because low seed quality can result in low productivity and profitability. Harvesting at 20 DAA provided the highest seed quality in all rice varieties. However, harvest at this time causes very high seed moisture, and it is recommended if good drying facility is available. If good drying facility is not available, it is recommended to harvest at 30 DAA because seed quality was still high although it was not as high as those harvested at 20 DAA. The standard germination of rice as seedling root length, seedling shoot length and total seedling length were associated with field

emergence and seedling growth rate, and the correlation coefficients (r) were in a range between 0.55 and 0.82 (Chhetri, 2009). In corn, Divsalar *et al.* (2016) found that the germination percentage was closely associated with root weight shoot weight of seedling, and it was also correlated with plant growth in the field. Sofiya *et al*. (2020) reported that the correlations among traits related to seed quality depended on germination conditions such as temperature and moisture.

Rice variety and harvesting time influenced seed germination percentage and mean germination time, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight of seedlings. Harvesting at 20 DAA resulted in the highest percentage of germination, and the seedlings took the least time to germinate in all rice varieties. Seedling weight accumulation was highest in the rice varieties at harvested at 20 DAA. The lowest germination percentage in Song Yod would be due to the rapid reduction in germination caused by long storage for six months.

Acknowledgements

The authors are grateful to King Mongkut's Institute of Technology Ladkrabang [2565-02-04- 006] for providing financial supports to this research.

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(Received: 12 November 2022, accepted: 28 February 2023)