# Varied Responses of System of Rice Intensification (SRI) to Medium and Short -aged Rice and Types of Planting Material in Central Plains of Thailand

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**Short Title: Age of rice and SRI**

**ABSTRACT**

**Background and Objectives:**The System of Rice Intensification (SRI) as one of the methods of producing rice under controlled water management is known to contribute to the increasing demand for food and ensuring water security and ecological balance of the environment. The performance of short- aged rice under SRI has not tested adequately. Hence a pot experiment was conducted to investigate the performance of short and medium-aged rice varieties and different types of planting materials in SRI.

**Materials and Methods:** Six treatments composed of 2 x 3-factor factorial combinations of two age groups of rice and three types of planting materials were tested in a Completely Randomized Design with three replicates each. Time for reaching different phenological stages, above and below ground growth parameters, and per plant yield parameters were assessed.

**Results:** The medium-aged rice (MAR) variety (115-day-old) showed its adherence to its exact life duration and phenological stages, while the short-aged (SAR) variety (90-day-old) extended its all phenological stages beyond its stipulated durations under SRI practices. The shoot and root growth parameters were significantly different among the two age groups. A significantly higher per hill grain weight was observed in the medium-aged rice variety compared to the short-aged variety. Short-aged rice varieties irrespective of the type of planting material extended the duration of their phenological stages

**Conclusions:** Short-aged rice extends its phenological stages and performs poor growth and offers less yield under the System of Rice Intensification inthe Central Plain of Thailand.

**Keywords:** Short-aged rice, phenology, growth, yield, SRI

## INTRODUCTION

The System of Rice Intensification (SRI), which was accidentally found in 1983 in Madagascar, is becoming popular currently for producing higher yields with lower consumption of water compared to conventional rice production suggesting an alternative to increasing water scarcity in the irrigated rice cultivation. This is an approach for increasing the yield of irrigated rice through integrated crop and resource management[1,2].

The SRI is one of the rice-producing methods which ultimately focus on food, economics, water securities, and ecological balance of the environment. Asian region pays greater concern in popularizing SRI, especially with its strength in acting against climatic change. The performance of different aged varieties of rice is an important criterion in SRI since there are rice varieties of different age groups adopted by farmers in different localities. However, the effects of the age of rice varieties for SRI have not beengiven adequate attention by many researchers in their SRI research work, except paying attention to the age of seedlings used for transplanting[3,4,5], alternate wetting and drying regimes[6], spacing[7,8], and method of planting [9] in the system. A few rice scientists have investigatedmainly medium- and long-aged rice varieties, but not the short-aged rice varieties. Nissanka and Bandara[10] have studied a 105-day rice variety and observed vigorous growth of plants in SRI producing a greater number of tillers and higher leaf area eventually giving high grain yields. Gupta [11] reported that the response of the SRI was better with 120-130-day-old rice cultivars in India. Vijayakumar *et al.* [12] observed higher yields during two consecutive years with a 110-day variety when transplantedwith 14-day-old seedlings in 25 x 25 cm spacing under the usual SRI water management compared to conventional production practices. Krishna and Biradarpatil[4] reported that 12-day-old seedlings produceda greater number of productive tillers per plant at the harvest compared to 8-, 16-, and 25-day-old seedlings of a medium-duration rice variety, ES 18 (120-day-old). However, the literature on the performance of rice in SRI with short-aged varieties is deficient. Therefore, this study was conducted to explore the feasibility of growing short-aged rice varieties in SRI by evaluating their phenology, growth, and yield performances

## MATERIALS AND METHODS

**Study area:** This study was conducted as a pot experiment in a plant house covered with a plastic roof (with a transmissivity of 93%) at the Agricultural Systems Experimental Station of the Asian Institute of Technology, Thailand (Latitude, 14$^{o}$ 04’N, Longitude 100$^{o}$37’E and MASL, 2.27) from February to July 2009. The soils of the site belong to the Rangsit Series, which is deep, very fine clayey and extremely acid sulfate, with pH (soil: $H_2O$ 1:1) of 4.5-4.9. The pH of the soil was raised to 6.2 by adding lime before filling the experimental pots.

**Treatments:**Six treatments were composed with 2 x 3 factorial combinations of two age groups of rice [viz. short-aged rice –SAR of 90-day-old and medium-aged rice MAR of 110-day-old] and three types of planting materials [viz. direct-seeded rice (DSR), transplanted rice with 8- ($TPR_8$), and 12-day-old seedlings – ($TPR_{12}$)], assigned to pots and arranged in a Completely Randomized Design (CRD) with three replicates for each treatment.

**Research procedure:** Pots were 0.6 m indiameter and0.8 m in height. A five (5) cm hole was made at the bottom of each pot and a PVC tube was fixed up with a removable cap to regulate water level during irrigation and to facilitate drainingof water during the non-irrigation period. Pots were filled with a mixture of lime-treated, cow dung-added (at the rate of 10,000 kg ha$^{-1}$) and well-plowed soils up to 0.7 m of height leaving 10 cm from the top.

During the initial two weeks, all pots were irrigated to help soils to settle down before commencing the study. After two weeks, two non-photoperiod sensitive rice varieties, namely Suphanburi 2 (SAR) and Pathumthani 1 (MAR) recommended to the Central plains of Thailand by the Department of Agricultural and Extension (DOAE), were established in the pots as per treatment schedule.

Rice was transplanted manually in all the pots. Pre-soaked and pre-germinated seeds were directly seeded in pots assigned for DSR.To produce 8- and 12-day-old seedlings a separate nursery was used. Direct seeding was done first. Eight-day old seedlings were then taken from the nursery and transplanted in the corresponding pots assigned for $TPR_8$, while TPR12 treatment pots seedlings were transplanted when the seedlings in the nursery were12-days old. This practice enabled all plants to be in the same age and growth stage and to expose to the same environmental conditions at the same time. A plant density of two seedlings per hill was maintainedwith 25 x 25 cm spacing within each pot. Accordingly, four planting hills were maintained in each pot. Pots were irrigated daily until the crop became well-established.

To assure and monitor the depth of water, indicator scales were placed in all pots. Then water from the nearby irrigation canal was pumped into the pots as per treatment to maintain a 3-5 cm deep water layer during the periods of irrigation. Re-watering was done when the water level depleted below 3 cm in each pot within the period of inundation. Two-week irrigationand two-week non-irrigation period were strictly practiced as water management cycles, which continued until flowering. After flowering, the water level in the pots was maintained to a depth of 5cm until grains reached the hard dough stage, i.e., two weeks before harvesting, and then drained out to facilitate grain drying. Pots were regularly hand weeded. Integrated pest management (IPM) practices were adopted for pest management.

The number of days taken for 50% of the plants to reach maximum tillering (MT), flowering, and harvesting was recorded. The number of tillers per hill was counted at MT, flowering, and harvesting. The plant height of each hill was measured and recorded at MT and floweringand the mean height was calculated. Leaf area per hill was estimated by measuring the length and breadth of each leafat flowering as described by Yoshida[13].

Yield data were obtained from all four hills in each pot. The number of productive tillers per hill and the number of filled and unfilled grains per panicle were counted and recorded. One hundred (100) grain weight was recorded after drying the grains in the sun followed by an oven drying at 80$^{o}$C until a constant weight was reached. The moisture content of grains of all hills was recorded using Grain Moisture Meter (Grainer II PM 300, Made in Japan). Later, grain yield was computed to a 14% moisture content.

After harvesting, all pots were turned upside down on the groundand the depths of the root systems were recorded using a meter ruler. Thereafter, complete root systems of all four planthills in each pot were carefully separated and washed with running water on a mesh (6.4 squares/cm) until all soilparticles disappeared from the root mass. Then roots were sun-dried and dry weights were recorded. A representative sample from each root system was taken, its weight was recorded and the total length measured using a meter ruler and the gridline intersect method[14]. Then the root weight to root length ratio was calculated. The total length of the root system was estimated using the root weight to root length ratio. Roots were then dried in an oven at 80$^{o}$C until aconstant weightwas reached, and dry weights of whole root systems were recorded. The shoot to root ratio was calculated using shoot and root dry weights.The solar radiation and temperature inside and outside the greenhouse were also recorded daily throughout the cropping period.

**Statistical analysis:** Analysis of variance (ANOVA) was performed for data as per Complete Randomized Design (CRD)and Fisher's Protected Least Significant Difference (LSD) was used for mean separation[15].

## RESULTS

### Weather

Weather data during the study period showed the temperature and solar radiation ranged from 26°C to 40°C and from 172.88-732.63 $Wm^{-2}$ inside, respectively, and from 27 to 37°C and 221.16- 1671.77 $Wm^{-2}$ outside the plant house, respectively (Fig. 1).

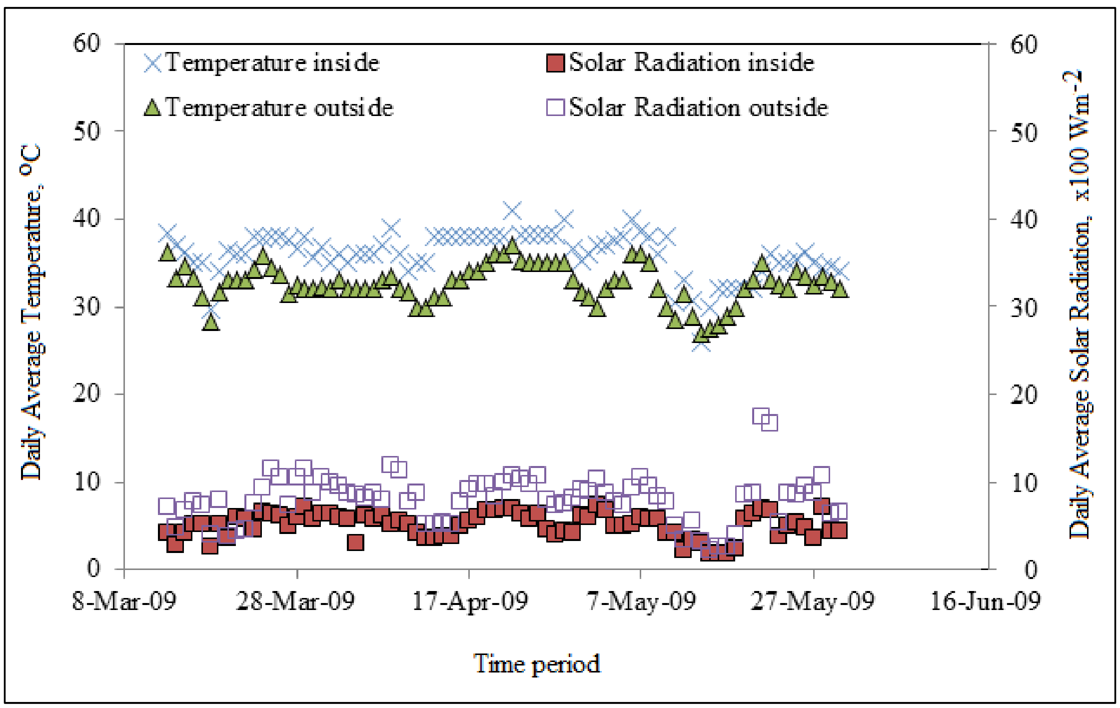


**Fig. 1: Variation of temperature and solar radiation in and out of the greenhouse**

### Growth Performances

**Plant Phenology**

The age of the rice variety, the type of planting material, and the interaction between the two factors did not significantly influence thetime to commence and 50% flowering as shown in Table 1. Similarly, the time of harvesting between SAR and MAR varieties also did not differ significantly against their 20-day age difference ofthe SAR variety. Flowering commenced between 72 and 77 days (i.e., a delay of 30-32 days), and between 79 and 81 days for MAR variety with a delay of 13-15 days from expected days. Fifty percent flowering occurred in 83-87 days for 90-day variety with a delay of 28-32 days, and in 86-90 days for MAR variety with a delay of 10-14 days from expected days as per Table 2.

Table 1: Effect of age of the variety and type of planting material and their interaction on reaching different phenological stages of rice

| **Analysis of variance** | | | | |
|---|---|---|---|---|
| Source of variation [1/] | DF | Mean squares | | |
| | | Beginning flowering | 50% flowering | Harvest |
| A | 1 | 117.55 | 18.00 | 2.72 |
| P | 2 | 15.50 | 46.33 | 122.38*** **2/** |
| A*P | 2 | 11.05 | 14.33 | 3.39 |
| Error | 12 | 13.44 | 7.44 | 1.17 |
| **Results** | | | | |
| Treatments | | Phenological stage, days | | |
| | | Beginning Flowering | 50% flowering | Harvest |
| **Age of rice variety (A)** | | | | |
| SAR | | 74.4 ± 3.9 **3/** | 85.3 ± 2.9 | 109.0 ± 4.9 |
| MAR | | 79.6 ± 3.4 | 87.3 ± 3.2 | 109.8 ± 3.8 |
| LSD (p=0.05) | | ns | ns | ns |
| **Type of planting material (P)** | | | | |
| DSR | | 78.2± 3.9 | 84.7± 39 | 113.7±1.4 |
| $TPR_8$ | | 75.2± 4.9 | 88.5±1.9 | 109.8±1.5 |
| $TPR_{12}$ | | 77.7± 4.6 | 85.8±3.3 | 107.7±0.8 |
| LSD (p=0.05) | | ns | ns | 1.5 |
| CV% | | 4.7 | 3.2 | 1.1 |

1/ A - Age of the rice variety; P-Type of planting material; DSR – Direct- seeded rice; $TPR_8$ –Transplanted rice with 8-day-old seedlings; $TPR_{12}$– Transplanted rice with 12-day-old seedlings.
2/ * - F value is significant at p=0.05; ** - p=0.01; and *** - p=0.001; ns – not significant at p = 0.05; 3/ Standard deviation of means

Both varieties reached the harvesting stage in 109 days from the date of establishment. However, the time of harvesting significantly varied due to the type of planting material: direct-seeded rice (DSR) reached the harvesting stage in 113 days fromthe establishment, which was significantly longer than that of transplanted rice of 8 and 12-days old. Similarly, 8-day-old rice also had a significantly longer time (almost 2 days) than12 day-old rice. There was a delay in reaching the harvesting stage compared to the expected days. When transplanted at the age of 12-days, the SAR variety took more than 14 days to reach the maturity stage when transplanted at the age of 12-days, while MAR took an extra six days as per Table 2.

Table 2. Expected and observed durations for reaching specific phenological stages of two rice varieties as influenced by age group and type of planting material in the System of Rice Intensification (SRI).

| Age of Rice Variety | Type of planting material 1/ | Commencement of flowering, | | 50% Flowering | | Harvesting | |
|---|---|---|---|---|---|---|---|
| | | Expected | Observed | Expected | Observed | Expected | Observed |
| | | -------------------------------- Number of days | | | | --------------------------- | |
| SAR | DSR | 45 | 75 | 55 | 83 | 90 | 114 |
| | $TPR_8$ | 45 | 72 | 55 | 87 | 90 | 109 |
| | $TPR_{12}$ | 45 | 77 | 55 | 86 | 90 | 104 |
| MAR | DSR | 66 | 81 | 76 | 87 | 110 | 113 |
| | $TPR_8$ | 66 | 79 | 76 | 90 | 110 | 111 |
| | $TPR_{12}$ | 66 | 79 | 76 | 86 | 110 | 106 |

1/ DSR – Direct seeded rice; $TPR_8$ - Transplanted rice with 8-day-old seedlings; $TPR_{12}$ - Transplanted rice with 12-day-old seedlings;

**Shoot Growth Parameters**

***Tiller number per hill***-The tiller number per hill was significantly influenced only by the type of planting material and that was only at maximum tillering, and by the age of rice variety at harvest (Table 3). Direct seeded rice had the highest tiller number (45 per hill) and was significantly greater ($p<0.01$) than rice established with $TPR_8$ and $TPR_{12}$ at maximum tillering. Rice transplanted with12-day-old seedlings had the lowest tiller number per hill, which was only 60.1% from the DSR. Transplanting at 8-day-old rice had a moderate tiller number per hill (41 tillers - a 9% reduction) but wasnot significantly different from DSR.

Towards flowering, there was an increase in the number of tillers per hill. It amounted to 28% for direct-seeded rice, 46% for transplanted rice with at 8-day-old seedlings, and 44.7% for transplanted rice with at 8-day-old seedlings. However, at the harvest, the tiller number was significantly influenced only by the age of rice variety. The MARvariety had a significantly greater tiller number (44 tillers/hill) than SARriceat harvest as per Table 3.

Table 3: Effect of age of the rice variety and type of planting material and their interaction on selected shoot growth parameters

**Analysis of variance**

| Source of variation[1/] | DF | Mean squares: Tiller number, no/hill: Maximum tillering | Flowering | Harvest | Plant height, cm: Maximum tillering | Flowering | Leaf area at flowering $m^2$/hill | Shoot biomass g/hill |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 17.60 | 33.35 | 361.81**[/2] | 567.85*** | 373.56** | 0.29*** | 190.71 |
| P | 2 | 562.71** | 220.79 | 53.01 | 1013.57*** | 177.18* | 0.29*** | 572.08** |
| A*P | 2 | 79.74 | 91.76 | 43.39 | 13.31 | 47.76 | 0.05*** | 699.80 |
| Error | 12 | 37.06 | 76.26 | 20.48 | 16.11 | 38.81 | 0.001 | 210.40 |

**Results**

| | Tiller number: Maximum tillering | Flowering | Harvest | Plant height: Maximum tillering | Flowering | Leaf area at flowering | Shoot biomass |
|---|---|---|---|---|---|---|---|
| **Age of rice variety (A)** | | | | | | | |
| SAR | 38.9±9.3 [3/] | 57.3±11.4 | 35.1±6.3 | 66.4±11.3 | 102.2±7.8 | 0.8±0.1 | 130.2±27.1 |
| MAR | 37.0±11.4 | 54.6±7.9 | 44.1±3.9 | 77.6±12.4 | 111.3±7.3 | 1.0±0.3 | 136.7±12.2 |
| LSD (p=0.05) | ns | ns | 4.9 | 4.0 | 6.4 | 0.09 | ns |
| **Type of planting material (P)** | | | | | | | |
| DSR | 45.6±6.8 | 58.4±7.5 | 42.9±5.1 | 83.8±7.7 | 112.9±7.5 | 1.1±0.3 | 144.7±16.2 |
| $TPR_8$ | 41.3±7.7 | 60.3±10.3 | 38.8±9.0 | 74.1±6.1 | 104.8±7.8 | 0.8±0.1 | 140.7±16.4 |
| $TPR_{12}$ | 27.1±4.5 | 49.0±7.8 | 37.1±5.6 | 58.1±7.3 | 102.6±8.3 | 0.7±0.1 | 114.9±17.1 |
| LSD (p=0.05) | 8.1 | ns | ns | 4.9 | 7.8 | 0.1 | 20.7 |
| CV% | 16.02 | 15.62 | 11.43 | 5.58 | 5.83 | 3.69 | 10.80 |

**1/** A - Age of the rice variety; P- Type of planting material ; DSR – Direct- seeded rice; $TPR_8$ –Transplanted rice with 8-day-old seedlings; $TPR_{12}$– Transplanted rice with 12-day-old seedlings; **2/** * - F values are significant at p=0.05; ** - p=0.01; and *** - p=0.001; ns – not significant at p = 0.05; **3/** Standard deviation of means.

***Plant height at flowering:***

Among the selected above-ground growth parameters, the plant height was influenced by the two main factors, i.e., age and type of planting material at maximum tillering and flowering. The MAR variety was significantly taller than that of SAR variety, and DSR was taller than TPR as stated in table 3. This is probably attributed to relatively longer vegetative periods of longer-aged rice compared to shorter-aged varieties and direct seeding compared to transplanting.

***Leaf area at flowering***:

Both age of the variety and the type of planting material, and their interaction had significant effects on leaf area per hill at flowering (Table 3 and Fig. 2). The interaction between the two main factors showed that the highest leaf area was in the MAR variety established by DSR and was significantly greater than the rest of the factor-level combinations. No other treatment combinations displayed significant differences.

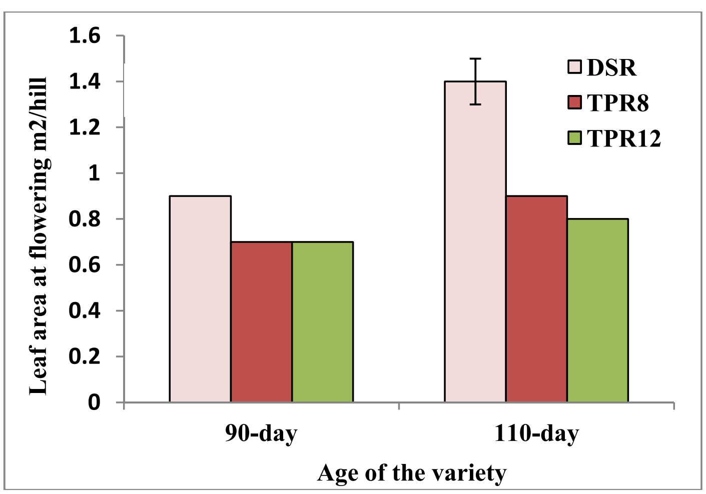


Figure 2. Effect of interaction between the age of rice and type of planting material on leaf area at the flowering of rice in SRI

***Shoot biomass:***

The highest shoot biomass was in DSR (144.9 g/hill) and it was significantly greater than $TPR_{12}$ (114.9 g/hill) (Table 3). There was no significant difference in shoot biomass between DSR and $TPR_8$ (140.7 g/hill). $TPR_{12}$ had the lowest shoot biomass.

### Root Growth Parameters

**Root depth (RD):** There were significant effects on root depth by the age of rice and type of planting material and their interaction as per Table 4. The interaction effect on root depth is shown in Fig. 3. The only significant increase in the root depth was found in the DSR of MAR variety, which had 85 cm, whereas the other root depths were in the range of 61 to 67 cm.

Table 4. Effect of age of the rice variety and type of planting material and their interaction on different root growth parameters

| **Analysis of variance** | | | | | |
|---|---|---|---|---|---|
| Source of variation[1/] | DF | Mean squares | | | |
| | | Root depth, cm | Total root length, m | Root biomass, g/hill | Shoot to root ratio |
| A | 1 | 364.50***[/2] | 12306.19** | 18.34** | 188.63* |
| P | 2 | 253.50*** | 1248.94 | 5.72* | 134.28* |
| A*P | 2 | 145.50*** | 817.15 | 2.93 | 88.79 |
| Error | 12 | 4.50 | 635.76 | 2.00 | 31.21 |
| **Results** | | | | | |
| **Age of the rice variety (A)** | | | | | |
| SAR | | 63.0±3.1[3/] | 164.0±20.9 | 4.8±0.9 | 27.4±9.0 |
| MAR | | 72.0±9.8 | 216.3±31.2 | 6.9±1.9 | 20.9±4.7 |
| LSD (p=0.05) | | 5.0 | 26.0 | 1.3 | 6.4 |
| **Type of planting material (P)** | | | | | |
| DSR | | 75.1±11.1 | 191.4±56.1 | 6.9±2.6 | 22.9±9.9 |
| $TPR_8$ | | 63.5±1.9 | 203.9±23.1 | 5.0±0.9 | 29.3±6.8 |
| $TPR_{12}$ | | 64.0±3.7 | 175.1±25.1 | 5.7±0.6 | 20.1±2.1 |
| LSD (p=0.05) | | 6.1 | ns | 1.6 | 7.9 |
| CV% | | 3.14 | 13.26 | 20.19 | 23.51 |

1/ A - Age of the rice variety; P-Type of planting material; DSR – Direct- seeded rice; $TPR_8$ –Transplanted rice with 8-day-old seedlings; $TPR_{12}$– Transplanted rice with 12-day-old seedlings. 2/ * - F value is significant at p=0.05; ** - p=0.01; and *** - p=0.001; ns – not significant at p = 0.05; 3/ Standard deviation of means

***Total root length (TRL):*** The age of rice variety had a significant influence on the total root length of rice, but neither the type of planting material nor the interaction between age and type of planting material showed significant effects (Table 4). The MAR varietyhad the highest and significantly greater TRL than that of the SAR variety.

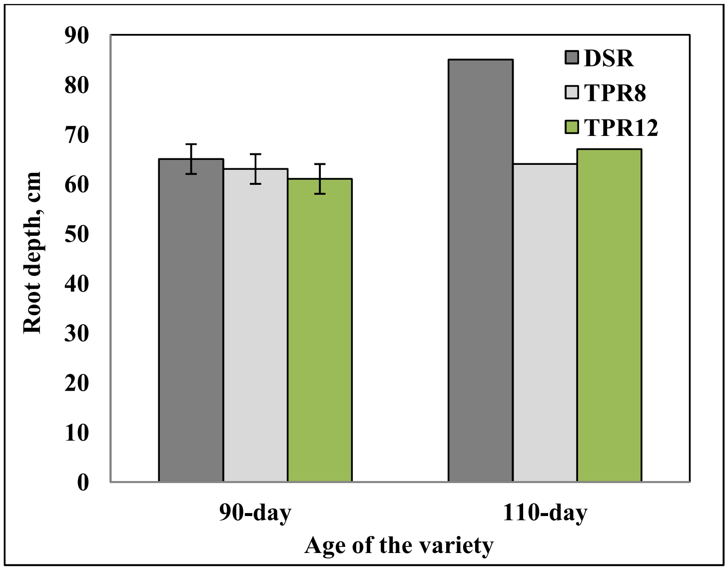


Figure 3. Effect of the interaction between the age of rice and type of planting material on the root depth of rice in SRI.

***Root biomass (RB)*****:** Root biomass per hill of rice was significantly influenced by both the age of the rice variety and the type of planting material (Table 4). There was no significant interaction between the two factors on root biomass. Of the age of the variety, MAR variety had significantly greater RB than the SAR variety, while DSR had significantly greater RB than both TPR. A longer growing period available for root development could have been the contributory factor for higher RB of DSR, and TPR appeared to have had some disturbance to root development due to uprooting and transplanting.

***Shoot to root ratio:*** Both the age of rice variety and the type of planting materials had significant effects on the shoot to root ratio, but there was no significant interaction between the two factors (Table 4). Between the two varieties used,the shoot to root ratio was highest in the SAR variety (27.4) compared to the MAR variety, while $TPR_8$ (29.3) among the types of planting material used had the highest shoot to root ratio. Both MAR variety and $TPR_{12}$had the lowest shoot to root ratio. The lower root biomass of the $TPR_8$ compared to $TPR_{12}$ has made a high S:R ratio of $TPR_8$ than $TPR_{12}$ which is a bit unrealistic.

**Yield and Yield Parameters**

***Panicle number per hill (PNH)–***The panicle number per hill was significantly influenced only by the age of rice variety as stated in table 5. There was neither the type of planting material nor their interactionhad any significant effect on the number of panicles per hill. The PNH was significantly greater only in the MAR variety compared to the SAR variety.

Table 5. Effect of age of the variety and type of planting material and their interaction on yield and yield parameters of rice

**Analysis of variance**

| Source of variation [1/] | DF | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Panicles, no/hill | Filled grains, no/panicle | 100-grain weight, g | Panicle length, cm | Panicle weight, g/panicle | Grain weight, g/hill | Spikelet sterility % |
| A | 1 | 361.54**[2/] | 5417.71* | 0.16** | 3.10* | 0.65* | 2417.44** | 19.18 |
| P | 2 | 106.11 | 3393.18 | 0.01 | 4.87** | 0.46 | 552.16* | 114.25* |
| A*P | 2 | 43.09 | 725.58 | 0.02 | 4.47** | 0.01 | 74.34 | 333.03** |
| Error | 12 | 20.48 | 619.60 | 0.01 | 0.62 | 0.09 | 131.95 | 18.81 |
| **Results** | | | | | | | | |
| **Age of rice variety (A)** | | | | | | | | |
| SAR | | 35.1±6.3[/3] | 165.6±35.9 | 2.2±0.1 | 29.9±1.5 | 3.3±0.2 | 62.8±16.6 | 9.9±6.9 |
| MAR | | 44.1±3.9 | 130.9±15.6 | 2.4±0.1 | 29.1±1.0 | 3.7±0.4 | 85.9± 8.9 | 11.9±9.5 |
| LSD (p=0.05) | | 4.9 | 25.5 | 0.1 | 1.1 | 0.3 | 11.2 | ns |
| **Type of planting material (P)** | | | | | | | | |
| DSR | | 42.9±5.1 | 166.9±30.6 | 2.3±0.1 | 29.4±0.8 | 3.4±0.3 | 81.4±11.2 | 14.1± 6.0 |
| $TPR_8$ | | 38.9±9.0 | 134.1±43.1 | 2.3±0.1 | 28.7±1.1 | 3.2±0.4 | 63.5±20.9 | 12.7±11.2 |
| $TPR_{12}$ | | 37.1±5.6 | 143.7± 8.1 | 2.3±0.2 | 30.5±1.4 | 3.8±0.3 | 78.3±16.4 | 5.9± 4.5 |
| LSD (p=0.05) | | ns | ns | ns | 1.3 | ns | 13.8 | 9.9 |
| CV% | | 11.43 | 16.69 | 4.24 | 2.66 | 8.68 | 15.44 | 9.67 |

1/ A - Age of the rice variety; P- Type of planting material; DSR – Direct- seeded rice; $TPR_8$ –Transplanted rice with 8-day-old seedlings; $TPR_{12}$– Transplanted rice with 12-day-old seedlings. 2/ * - F value is significant at p=0.05; ** - p=0.01; and *** - p=0.001; ns – not significant at p = 0.05; 3/ Standard deviation of means;

***Number of filled grains per panicle (FGNP) –***Similar to panicle number per plant, the number of filled grains was significantly influenced by the age of rice only, but the grain number was higher in SAR (165.6) than the MAR (130.9) as clearly mentioned in table 5.

***100-grain weight (HGW):*** The 100-grain weight was also significantly influenced by the age of rice variety and MAR variety had a higher grain weight than SAR. Neither type of planting material nor the interaction between the two factors had any significant effect.

***Panicle length (PL)***–Both the age group of rice and the type of planting material as well as the interaction between the two factors had significant effects on the panicle length (Table 5). The highest panicle length was in SAR variety with $TPR_{12}$, which was significantly greater than the other factor combinations (Fig. 4). The next highest was in MAR variety established with direct seeding. The lowest panicle length was in MAR with $TPR_8$.

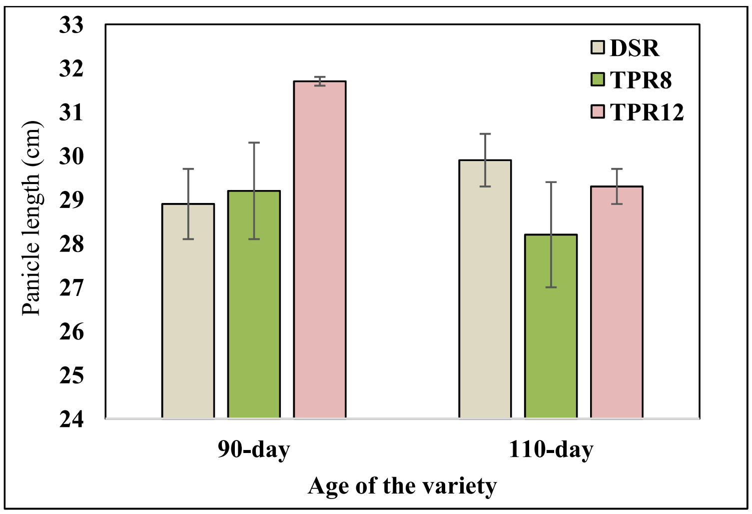


Figure 4. Effect of the interaction between the age of rice and type of planting material on panicle length.

***Panicle weight (PW):*** The panicle weight was significantly influenced by the age of rice, in which MAR variety had a significantlygreater panicle weight (3.7g) compared to SAR variety (3.3 g).

***Grain weight per hill (GWPH):*** There was a significant influence on grain weight per hill by both age and type of planting material of rice (Table 5). There was no interaction between the factors that significantly influenced the GWPH. Of the two factors, MAR variety had a significantly higher grain weight per hill (85.9g) compared to SAR variety (62.8 g). DSR had a significantly greater per hill grain weight (81.4g) compared to $TPR_8$. The per hill grain weight of DSR was not significantly different from $TPR_{12}$ (78.3 g).

***Spikelet Sterility % (SS):***The spikelet sterility percentage was significantly influenced by the two factors and their interaction (Table 5), and the interaction effect is shown in Fig. 5. The spikelet sterility was highest in MAR variety with $TPR_8$(14.1%). The lowest spikelet sterility was in the MAR rice variety with $TPR_{12}$. However, the spikelet sterility of SAR variety was non-significantly lower when combined with $TPR_{12}$ compared to the other two planting materials.

## DISCUSSION

The phenology of rice usually is sensitive to water stress during the vegetative period[16,17] and dry weather defers flowering fromone to several weeks. However, the reproductive and grain filling periods from flowering to physiological maturity are often least modified in conventionally grown rice regardless of the age group; and this period is usually consistent around 30-35 days under any change in rainfall and resource supply in conventional rice production systems[18]. The SAR ricevariety completed vegetative growth in nearly 60 days, while it took 90 days for the MAR variety under normal growing conditions.

The results of the current study showed a deviation from both vegetative and reproductive growth durations under SRI water management practices. Commencement of flowering of $TPR_8$ had extended from 45 to 72 days (by 27 days), $TPR_{12}$ from 45 to 77 days (by 32 days), and by 30 days with DSR (Table 2). Fifty percent flowering also extended from 55 days to 83 days (by 28 days)in DSR to 86 and 87 days (by 31 and 32 days) in $TPR_{12}$ and $TPR_{8}$, respectively. As a result, harvesting time (maturity) extended from 90 days to 104 and 109 days in $TPR_{12}$ and $TPR_{8}$, respectively, and 114 days in DSR. Overall, SAR variety delayed its maturity period by 14 days with $TPR_{12}$taking 114 days, by 24 days with DSR taking 104 days, and $TPR_{8}$ was moderate taking additional 19 days (109 days from establishment).

The MAR variety also delayedits commencement of flowering by 13 to 15 days, 50% flowering by 10-14 days in SRI. However, rice plants in $TPR_{12}$ reached harvesting time 4 days earlier (106 days against 110 days of expected maturity). The harvesting time of $TPR_{8}$ and DSR reached 111 and 113 days, respectively, which is an ignorable variation in the maturity period. The differences in reaching phenological stages were attributed to soil drying resulted from withholding irrigation for two weeks leading to water stress and thus its recovery time during this period. Water stress appeared to have slowed down growth and development related processes thus extending the time taken to recover from the stress with follow up wetting.

The drying period induced by suspending irrigation in alternate wetting and drying (AWD)seemed tomodify crucial physiological activities; in this situation, the vegetative period was eventually extended in both age groups (SAR and MAR). This could be attributed to the additional time required to fulfill keyphysiological and phenological requirements that will eventually ensure the plant to be in a state to support reproductive functions. Although it has been reported that long-aged rice varieties have a better defense than short-aged varieties in responding to water stresses that occur during the vegetative period [19], this study shows that when the water stress disturbs physiological processes supporting key developmental activities and reproductive functions, rice plants seem to make all efforts to support its reproductive function, even by extending the vegetative growth period to fulfill growth and developmental needs before reaching flowering. There is literature indicating that water stress promoting the synthesis of Abscisic Acid (ABA) in the rice plant that ensures increasing partitioning of assimilates to root development, prolonging leaf functions, and improving tolerance to water stress[20,21]. Although the reproductive period is known to be more or less consistent, Garrity, and O'Toole[22] reported that it is also sensitive to water stress and variable.Being grain filling period critical in determining the size and weight of grains that contribute to final yield, SRI adopts continuous inundation to 5 cm depth during the reproductive and grain filling periods to avoid water shortage or stress and ensure adequate water availability so that the rate of assimilate transfer to grains would be maintained as needed. The issue of water stress occurs in SRI during the vegetative period because of alternate wetting and drying. After two weeks of flooding, suspension of water availability for two weeks may gradually expose the rice plants to water stress which seems to stimulate the plant's recovery and physiological processes in favour of yield components. In this aspect, the synthesis of cytokinins governs the phenological development of the rice plant. It has been reported that cytokinins promotes several growth functions such as deep root development ensuring the maintenance of water uptake following water stress periods as well as during follow up water stress periods[23], maintenance of functioning leaves over a longer period by delaying leaf senescence and maintaining the photosynthetic capacity of existing leaves[24,25], increasing tiller production and tiller development with the support of the root and leaf functioning[23,24,26], etc., and all these positive changes areeffectively manipulating vegetative period to produce the optimum leaf area and increasing the number of tillers and spikelets. These two components eventually ensure higher yields of ricein SRI compared to the conventionally grown rice crop. Therefore, more than the stipulated period of 90-days of SAR, prolonging the vegetative period has taken place to ensure its potential yield, which led its overall growth period to take a full-time duration similar to the maturity period of MAR variety. This period seemed to have not been required for MAR variety as the period of water stress resulted due to suspension of water supply and the periods for stress recovery and growth promotion with follow-up flooding were adequatefor its usual growth and development periods. This agrees with Stoop[19] who reported that longer duration varieties can recover physiological drawbacks that resulted from water stress during vegetative periods due to their longer vegetative growth period compared to a short-day variety like 90 days having 60 days of the vegetative period under SRI. Latif *et al.*[28] also reported similar results with longer duration varieties indicating that such varieties perform better in SRI giving higher yield than short-aged and medium-aged rice varieties. Similar findings were also reported by Raju and Sreenivas[29] by evaluating 90-, 110-, 130-,135- and 145-day-old varieties. In their work, 145-day-old varieties performed better than medium (110-, 130-, and 135-day-old) and short-aged (90-day-old) rice varieties, specifically having a significantly higher tiller number in the longer duration variety.

Katayama[29] reported that phyllochrons are responsible for ensuring the number of tillers formed in rice. Longer duration rice varieties have a longer vegetative period and these varieties can complete full phyllochrons[19] since the vegetative period of these varieties is long enough to complete full phyllochrons even when rice is established with either by direct seeding or early transplanting. Youki *et al.*[30] reported that the developmental change of phyllochron is highly dependent upon the genotypes and the growth duration of the crop. The varieties with shorter vegetative periods possess faster growth phases, and any type of stress including water stress could drastically reduce the growth rate thus delayingthe reach of specific phenological stages. For short-aged rice varieties, water stress if occurred during the vegetative period will provide only a short period to recover from the stress once the stress is alleviated by irrigating the crop, compared to longer-aged rice varieties[31]. This shows that only those varieties that could prolong the vegetative period under water stress conditions would appear to be suitable for SRI, in case if short-aged rice varieties are used. The SAR variety (Suphan Buri 2) used in this study shows its growth plasticity and hence suitability for SRI when only the growth plasticity is concerned.

Transplanting young seedlings of 8- to 10-day-old and not after 15days preserves the optimum tillering and rooting potential.This may be reduced if transplanting is done after the 4$^{th}$ phyllochron, i.e., 15 days after emergence[1]. However, three types of planting materials used in the present experiment were within8-12-days range, and hence plants were able to make use of the maximumtillering potential of the rice plant. Direct seeded rice (DSR) irrespective of the age of the variety had greater plant height than transplanted rice ($TPR_8$ and $TPR_{12}$). The DSR experiencedminimumdisturbance after establishment and hence produced taller plants compared to transplanted rice plants (TPR). Medium-aged variety (MAR) hadtaller plants compared to SAR in this study. Leaf area per plant was significantly greater with DSR of MAR variety than that of SAR variety. Longer vegetative period and higher tiller production of the long age variety were the main reasons for contributing to greater leaf area of MAR variety than that of SAR variety. This was previously reported by Schnier *et al.*[32], Dingkuhn *et al.*[33], and Ginigaddara and Ranamukhaarachchiin[9].

Root biomass was significantly greater in MAR variety compared to SAR variety. This was due partly to the ability of longer aged varieties to produce greater root mass compared to shorter aged varieties. However, mediation of deep root development by cytokinin under water stress conditions seemed to have also contributed to increased root biomass as reported by Ookawa *et al.*[23]. The lower shoot to root ratio of MAR with$TPR_{12}$ indicates relatively higher root weight in the treatments compared to those with higher shoot to root ratio, which is an adjustment of the root systems to maintain plant water uptake during the water stress period and hence the photosynthetic capacity. Since SRI induced water stress during the period of suspension of irrigation, adjustment of the shoot to root ratio indicates the ability of rice plants to grow deeper in search of water to overcome the periods of water stress. $TPR_8$ of this study has shown lower root depth and root biomass and hence higher S:R ratio when compared to the $TPR_{12}$ which should havebeen theother way around. The continuous standing water layer in the pots after PI may have retarded the root growth of $TPR_8$. Thakur *et al.*[34] have proved that a long-standing continuous 5 cm water layer of the SRI field after PIis not advisable compared to continuing with AWD as it may lead to retardation of the growth of the rice plants in addition to wasting water at the same time.

The significantly higher panicle weight per plant, 100-grain weight, and grain weight per panicle of the medium-aged rice variety (MAR) than that of short-aged rice variety (SAR) explain the mechanisms contributing to better performance of medium duration varieties than shorter duration varieties in SRI. Tolerance to stress and the availability of time in the vegetative phase to adjust to stresses occurring might have been the reasons for this result. The higher per hill grain yield of DSR in shorter duration rice variety might be due to the least disturbance for the plant when established with direct seeds than transplanting.

## CONCLUSION

In conclusion, 90-day rice variety irrespective of the type of planting material used in the current study showed weaker performance in the System of Rice Intensification with the extension of their phenological stages, performing poor growth, and lowering yields compared to 110-day rice variety in the Central Plain of Thailand. This study indicates the suitability of the 110-day variety compared to the 90-day variety for SRI. However, further experiments would be recommended under field-level assuring inducement of water stress with the suspension of irrigation to confirm the findings further. In cases where soil moisture depletion induced by the AWD leading to water stress in the sub-surface soil profiles is complemented by water in deeper layers due to deep root growth, the benefit of cytokinin promoting growth and yield advantages in SRI may be hindered. In this respect, the identification of a characteristic site in a suitableenvironment for further studies would enableus to confirm the results of the current study.

**ACKNOWLEDGMENT**

Authors thank the Government of Norway for providing a scholarship for graduate studies of the first author and Asian Rice Foundation, the USA for partial financial assistance for in-depth studies at the Asian Institute of Technology, Thailand.

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