International Journal of Agricultural Technology 2015 Vol. 11(2): 373-389
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effects of Number of Seedlings on Growth, Yield, Cost and Benefit of 2 Rice Genotypes in Transplanted Fields

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Wiangsamut, B., Umnat, P., Koolpluksee, M. and Kassakul, W. (2015). Effects of number of seedlings on growth, yield, cost and benefit of 2 rice genotypes in translated fields. International Journal of Agricultural Technology 11(2):373-389.

Abstract This experiment was conducted during the dry season of December, 2010 until May, 2011, in the farmer's irrigated rice fields at Suan Luang village, Pongpawaey Subdistrict, District of Den Chai, Phrae province in Thailand to assess plant growth, yield, cost and benefit of RD14 and San-pah-tawng1 rice genotypes grown in transplanted fields under crop establishment methods using 1, 2, 3, and 4 seedling(s)/hill. Plant height of RD14 rice genoype was significantly taller than San-pah-tawng1 rice genotype. Grain yield of RD14 rice genotype was significantly higher than San-pah-tawng1 rice genotype; mainly due to RD14 rice genotype having had higher filled grain number per panicle and harvest index. Grain yield was, however, influenced by crop establishment method and rice genotype as RD14 rice genotype grown under crop establishment method using 1 seedling/hill yielded significantly higher than the controlled treatment (crop establishment method of RD14 rice genotype using 4 seedlings/hill). The two rice genotypes grown under crop establishment methods using 4 seedlings per hill had higher costs of production than other crop establishment methods using lesser number of seedlings per hill, mainly due to the higher use of seed rate per hectare for seedling preparation that raised the cost of production. The seeds' cost for seedling preparation for RD14 rice genotype under crop establishment methods using 1 seedling/hill could be saved by about 75% compared to that crop establishment method using 4 seedlings per hill. The net profit derived from RD14 rice genotype grown under crop establishment methods using 1 seedling/hill was considerably higher by 46% than of the controlled treatment. Therefore, the crop establishment method using 1 seedling/hill for RD14 rice genotype was the most feasible for investment in transplanted rice production indicated by the highest value of benefit-cost ratio (B/C ratio is 1.17) compared to the rest of the treatments.

Keywords: RD14, San-Pah-Tawng1, yield, harvest index, benefit-cost ratio

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Introduction

Rice (*Oryza sativa*) is an economic, and is the most important food crop in Thailand. Thailand's paddy rice output in 2013–2014 is likely around 34 million tons (Oryza.com, 2014). The total area under rice is estimated to be about 11 million ha representing approximately 40 percent of the cropped land area (Kupkanchanakul, 2000). Rice cultivation is around 2 ha/household (Office of Agricultural Economics, 2011). Approximately 353 grams of rice is consumed per day (for a Thai person with age above 3 years old) (National Bureau of Agricultural Commodity and Food Standards, 2010). Less than 20 percent of the total rice growing area is under irrigated conditions where rice can be grown not only in the wet season but also in the dry season because irrigation water supply is available. The annual production is produced in the dry season when average yield is in the range of about 4.31 t/ha (Kupkanchanakul, 2000). Various cropping systems are applied all over the country, but the transplanting method from the rice seedlings is the most famous among Thai farmers. Transplanting is becoming attractive in irrigated rice areas to increase yield per unit of growing area. Thai farmers, however, usually transplant at least 4 seedlings per hill which caused low grain yield. This is supported by Kanachareonpong (1994) who reported that grain yield of Jasmine rice 105 differed significantly among different number of seedlings per hill, 3 seedlings per hill yielded higher than 1 and 5 seedlings per hill. Natirong *et al.* (1994) also found that planting with 3 seedlings per hill has a tendency to obtain the highest grain yield of Japanese rice followed by 5 and 1 seedlings per hill. However, grain yields produced by 3 and 5 seedlings were not significant. Zhang and Huang (1990) reported that seedlings (30-day old) of the rice var. E Wan 5 were transplanted at 1–5 seedlings/hill. The seed set rate was the most stable yield component, followed by 1,000-grain weight, plant height, panicle length, and harvest index. The most unstable traits were grain yield/plant, total weight/plant, and panicle number/plant. The highest yield was obtained with 2–3 seedlings per hill. Similarly, Hasanuzzaman *et al.* (2009) reported that transplanting with 2 seedlings per hill gave a grain yield higher than those of 1, 3, and 4 seedlings per hill at plant spacing of 20cm x 20 cm. Faruk *et al.* (2009) also reported planting with a 14-day old seedling, 2 seedlings per hill produced the highest grain yield and yield components. Wiangsamut *et al.* (2006) and Wiangsamut and Mendoza (2008) cited that a high grain yield is positively related to an increase of harvest index. This value indicated the ability of assimilate translocated from accumulated organs or synthesized source or both accumulated organs and synthesized source to the panicle and grains. Dingkuhn *et al.* (1990) reported a high accumulated shoot dry weight can translocate assimilate into the panicle and its grain efficiently, and resulting in a higher grain yield as compared with those plants that have a low shoot dry weight. However, grain yield depends on other biofactors and abiofactors such as management practices from the young plant up to harvest, microclimate, plant phynotype including its genetic characteristics.

System of Rice Intensification (SRI) is introduced to initiate the principle of less input and more output. This system originated in Madagascar by Fr. Henry de Laulanie in 1980s that developed a new concept of single seedling transplantation (World Bank Institute, 2008). Accordingly, 36.54% of total labour force lives in rural areas, and involves in agricultural activities where rice production is the main source of income (Bank of Thailand, 2011a). In the past, one purpose of producing rice was to maintain household's food security, and sell the rest to neighbors (Arayaphong, 2012). Later on, population and economic growth accelerated the demand of rice, so farmers had to intensify rice production in order to meet the increased demand. Using more inputs (i. e. using more seedlings for transplanting) leads to higher production cost, which means that a farmer has to produce more to cover the cost, and fluctuated market price affects production cost and income (Arayaphong, 2012). Hence, there is a need to investigate the effect of number of seedling per hill on plant growth, grain yield, cost and benefit of 2 rice genotypes grown in transplanted fields hoping that the Thai farmers can have appropriate alternatives to produce more rice with low cost of production, and that can increase their income. The study aimed to assess plant growth, yield, cost and benefit of RD14 and San-pah-tawng1 rice genotypes grown in transplanted fields under crop establishment methods using 1, 2, 3, and 4 seedling(s)/hill**.**

Materials and methods

The experiment was conducted during the dry season of December, 2010 until May, 2011. This study was done in the irrigated areas of the rice farmer. It is located at Suan Luang village, Pongpawaey Subdistrict, District of Den Chai, Phrae province, Thailand. The two popular glutinous rice genotypes, RD14 and San-pah-tawng1, were selected and were tested. The transplanted rice field condition was silt loam soil with soil particles of 15.02% sand, 62.81% silt, and 22.17% clay. Soil properties comprised of pH (6.17), electrical conductivity (240.50µ S/cm), organic matter (2.02%), available phosporus (21.54 ppm), p*hotassium* (37.65 ppm), c*alsium* (1,343.5 ppm), and zinc (0.71 ppm). This experiment was laid out in a split plot design with arranging treatments in randomized complete block design (RCBD), replicated 4 times. The two rice genotypes (RD14 and San-pah-tawng1) occupied in the mainplot treatments. The four crop establishment methods [1, 2, 3, and 4 seedling(s) per hill] occupied in the subplot treatments. Total mainplot area was 1,568 m^2. Total subplot number was 32 subplots. Each subplot area was 7 m x 7m (49 m^2). A hand tractor was used for land preparation with a plow followed by land leveling in a paddled soil condition. On the next day, pre-germinated rice seeds (24-h soaking and 48-h incubation) were sown in a prepared paddled soil fields in preparation for the seedlings. The 23-day old seedlings were pulled out of the nursery bed and were then transplanted in the prepared fields at the same day with the plant spacing of 25 cm x 25 cm using 1, 2, 3, and 4 seedling(s) per hill, respectively. The 4 seedlings per hill were assigned to be a controlled treatment (farmers' cultural practice). The 15-15-15 chemical fertilizer used as basal fertilizer with the application rate of 333.32 kg/ha was broadcasted in the transplanted rice fields one day after transplanting. An assessment of leaf chlorophyll was done by a chlorophyll meter (SPAD reading) before applying the nitrogen fertilizer (Urea fertilizer). The indicator of the regular SPAD readings is above the number 36. It is assumed that there is still enough nitrogen present in the leaves; therefore, nitrogen application is not required. A 46-0-0 chemical fertilizer (Urea fertilizer) was equally applied twice for the entire crop growing period; 65.19 kg/ha at early tillering stage (29 days after sowing (DAS) or 16 days after transplanting (DAT)), and 65.19 kg/ha at late tillering stage (47 DAS or 34DAT). The total amount of urea fertilizer applied was 130.38 kg/ha. The standing water was maintained in the transplanted rice fields for the entire crop growing period, except two weeks before harvest; the fields were drained to stimulate rice maturity and facilitated to rice harvest. Weeds, insects and pests were controlled as necessary.

The plant growth parameters such as plant height, panicle number per square meter, and shoot dry weight per square meter for RD14 and San-pah-tawng1 rice genotypes, were made at physiological maturity stage (at harvest) 123 DAS (or 100 DAT) and 119 DAS (or 96 DAT), respectively. Five hills in each subplot were tagged, and then plant height was measured in a unit of centimeter (cm)/plant using a ruler from the soil to the highest tip of the plant by stretching. Randomized plant samples of two rice genotypes (RD14 and San-pah-tawng1) were taken three times (3 locations; each location was 1 m x 1m (1 m^2) corresponded to 16 hills) in each subplot at harvest. Then the panicle number was counted in a unit of number (no.)/square meter (m^2). Same plant samples (except roots due to the difficulties of collecting) were used to measure the shoot dry weight and yield components (1,000-grain weight, filled grain number per panicle, panicle number per square meter including percent filled grain number and harvest index). These plant samples were separated into panicles (grains and rachies), leaves and leaf sheaths, and stems were then placed in a dry oven at 80°C until it has all dried. All the dried samples were weighed and recorded. Shoot dry weight was computed as the sum of panicles, leaves, leaf sheaths and stems in a unit of gram (g)/m^2. Filled grains were isolated and counted for one thousand grains, then were weighed in a unit of gram (g) basis. Filled grain number per panicle was computed in a unit of number (no.)/panicle. Percent filled grain number was equivalent to a numerator (filled grain number per panicle) multiplied it by 100 and divided it by a denominator (total grain (filled grains and unfilled grains) number per panicle) in a unit of percent (%). Harvest index (HI) was calculated from a numerator (total filled grain dry weight) and divided it by a denominator (total shoot dry weight) in a unit of dimensionless.

Rice plants were cut from the 3 m x 2 m (6 m^2) area for grain yield per unit of growing area. Then, plant samples were threshed to obtain the whole grains of each subplot and were placed in a dry oven at 80°C for 48 hours, and then all the grains were stabilized at 14% moisture content (14% MC). Subsequently, grain yield in a unit of kilogram (kg) per 6 m^2 was converted into a unit of ton per hectare (t/ha) basis.

The costs and benefits of 2 rice genotypes were collected and recorded from different crop establishment methods using 1, 2, 3, and 4 seedling(s) per hill for a single growing season. The gross benefits and gross costs were computed in the unit of baht per hectare per single growing season. After that, the benefit-cost ratio (B/C ratio) was also computed as it is the ratio of the gross benefits to the gross costs. Net profit and net loss were computed as the value of gross benefits minus the value of gross costs in the unit of baht per hectare per single growing season. All plant data were analyzed using the Statistical Analysis System (SAS) program. Means comparisons were done using the Duncan's Multiple Range Test (DMRT). Data on costs and benefits of 2 rice genotype were derived from different crop establishment methods using 1, 2, 3, and 4 seedling(s) per hill and were completed using Simple Benefit-Cost Analysis.

Results

Regardless of crop establishment method, plant height of RD14 rice genotype was significantly taller than San-pah-tawng1 rice genotype (Table 1). Panicle number per square meter, shoot dry weight per square meter, and percent filled grain number of 2 rice genotypes, however, were not significantly different (Tables 2, 3, and 4). RD14 rice genotype had significantly higher filled grain number per panicle, lighter 1,000-grain weight, greater harvest index, and better grain yield than San-pah-tawng1 rice genotype (Tables 5, 6, 7, and 8).

Regardless of rice genotype, it was found that plant height, panicle number per square meter, shoot dry weight per square meter, percent filled grain number, filled grain number per panicle, 1,000-grain weight, harvest index, and grain yield were not affected by crop establishment method (Tables 1, 2, 3, 4, 5, 6, 7, and 8).

There were no interaction between crop establishment method and rice genotype on plant height, panicle number per square meter, shoot dry weight per square meter, percent filled grain number, filled grain number per panicle, 1,000-grain weight, and harvest index except grain yield (Tables 1, 2, 3, 4, 5, 6, 7, and 8).

Grain yield for RD14 rice genotype was significantly the highest under crop establishment method using 1 seedling per hill, but this grain yield was not significantly different from using 2 and 4 seedlings per hill; while for San-pah-tawng1 rice genotype, it was the lowest under crop establishment method using 1 seedling per hill. The grain yields of 2 rice genotypes were intermediate between the abovementioned values under the rest of the crop establishment methods (Table 8).

Grain yields (hulled rice grains at 14% MC) of 2 rice genotypes, RD14 and San-pah-tawng1, under crop establishment methods using 1, 2, 3, and 4 seedling(s) per hill were 6.19, 5.74, 5.68, 5.93, 4.25, 4.92, 5.28, and 5.39 tons/hectare (t/ha), respectively (Table 8). The costs of production were 47,373, 47,510, 48,049, 48,904, 45,374, 46,665, 47,635, and 48,349 baht/ha, respectively (Table 9). The selling price of the hulled rice grains was at 9 baht per kilogram (kg). The gross benefits were 55,710, 51,660, 51,120, 53,370, 38,250, 44,280, 47,520, and 48,510, respectively (Table 9). The net profits obtained ranged from more to less are as follows: 8,337 baht/ha derived from RD14 rice genotype grown under crop establishment methods using 1 seedling/hill, 4,466 baht/ha derived from RD14 rice genotype grown under crop establishment methods using 4 seedlings/hill, 4,150 baht/ha derived from RD14 rice genotype grown under crop establishment methods using 2 seedlings/hill, 3,071 baht/ha derived from RD14 rice genotype grown under crop establishment methods using 2 seedlings/hill, and 161 baht/ha derived from San-Pah-Tawng1 rice genotype grown under crop establishment methods using 4 seedlings/hill, respectively, while the rest were in the net loss (Table 9). The most feasible for investment in transplanted rice production of RD14 rice genotype was under the crop establishment method using 1 seedling/hill indicated by its value of benefit-cost ratio (B/C ratio) which was more than 1 (1.17). Only this value was higher than the controlled treatment (crop establishment method using 4 seedlings/hill for RD14 rice genotype, B/C ratio is 1.09) (Table 9). Considering San-pah-tawng1 rice genotype only, it was found that no other crop establishment method used could replace the use of 4 seedlings/hill as the value of B/C ratio under crop establishment method using 4 seedlings/hill was the highest at 1.00 (breakeven), while the rest of the values were less than 1 (in loss) under crop establishment method using 1, 2, and 3 seedling(s)/hill (Table 9).

Discussion

Plant height was 109.71 cm for RD14 rice genotype, while it was 105.30 cm for San-pah-tawng1 rice genotype. Plant height of RD14 rice genoype was taller than San-pah-tawng1 rice genotype by about 4.41cm. The Bureau of Rice Research and Development (n.d.) agreed with the study reported that plant height of RD14 rice genotype was 105–120 cm, but disagreed about San-pah-tawng1 rice genotype reporting that its plant height was 119 cm, which was evidently taller than the result from the researchers' study by about 13.97 cm. This was due to the different environmental conditions of crop establishment methods.

Grain yield of RD14 rice genotype was significantly higher than San-pah-tawng1 rice genotype by about 15.79% (or almost 0.93 t/ha). The lighter 1,000-grain weight of RD14 rice genotype could compensate with its higher filled grain number per panicle and greater harvest index, consequently resulting in a higher grain yield. An increase of harvest index is positively related to a high grain yield (Wiangsamut *et al.* (2006), and Wiangsamut and Mendoza (2008)) as the value of harvest index indicated the ability of assimilate translocated from accumulated organs or synthesized source or both accumulated organs and synthesized source to the panicle and grains, resulted in a higher filled grain number per panicle and consequently a higher grain yield of RD14 rice genotype than San-pah-tawng1. IRRI (1987) and Dingkuhn *et al.* (1990a) reported that growth dynamics and partitioning patterns of irrigated rice depend on cultural practices, particularly on planting method. While only the heavier 1,000-grain weight of San-pah-tawng1 rice genotype could not compensate with its lower filled grain number per panicle and lower harvest index, resulting in a lower grain yield. However, there was interaction between crop establishment method and rice genotype on grain yield, as grain yield of RD14 rice genotype was the highest under crop establishment method using 1 seedling per hill while grain yield of San-pah-tawng1 rice genotype was the lowest under crop establishment method using 1 seedling per hill. The highest grain yield of RD14 rice genotype under crop establishment method using 1 seedling was mainly due to having had the highest filled grain number per panicle, percent filled grain number and harvest index, and although the filled grain number per panicle, percent filled grain number and harvest index under all the crop establishment methods were not statistically different. The lowest grain yield of San-pah-tawng1 rice genotype under crop establishment method using 1 seedling was mainly due to having had the lowest filled grain number per panicle, lowest percent filled grain number and lowest harvest index.

The higher costs of production was found to be from RD14 and San-pah-tawng1 rice genotypes grown under crop establishment methods using 4 seedlings per hill, with 48,904 baht/ha, and 48,349 baht/ha, respectively. These costs of production were similar and both costs of production were higher than the other crop establishment methods of 2 rice genotypes using lesser number of seedlings per hill. This was mainly due to the higher use of seed rate per hectare for seedling preparation of 2 rice genotypes under crop establishment methods using 4 seedlings per hill, resulted in a higher cost of production. The seeds' cost for seedling preparation for RD14 rice genotype under crop establishment methods using 1 seedling/hill could be saved by about 75% compared to that under crop establishment method using 4 seedlings per hill. The selling price of the hulled rice grains was the same at 9 baht/kg for the two rice genotypes. The Ministry of Commerce has been tasked by the military government to come up with measures to keep the price of rice paddy between 8,500–9,000 baht per ton ($262-277/t) (USDA Foreign Agricultural Service, 2014). The gross benefit of RD14 rice genotype under the crop establishment method using 1 seedling per hill was the highest at 55,710 baht/ha due to its production of highest grain yield (6.19 t/ha) compared to the rest treatments, resulting in the highest net profit for RD14 rice genotype. This net profit was considerably higher by 46% than the net profit obtained from the controlled treatment (crop establishment method using 4 seedlings per hill for RD14 rice genotype). This indicated that the crop establishment method using 1 seedling per hill for RD14 rice genotype could replace the crop establishment method using 4 seedlings per hill. Moreover, the crop establishment method using 1 seedling per hill for RD14 rice genotype was the most feasible for investment in transplanted rice production as found in this study indicated by the highest value of benefit-cost ratio at 1.17. The lowest gross benefit was found to be from San-pah-tawng1 under the crop establishment method using 1 seedling per hill due to its lowest grain yield produced that resulted in a net loss compared to the controlled treatment (crop establishment method using 4 seedlings per hill for San-pah-tawng1 rice genotype). With this result, it is suggested that the crop establishment method using lesser number of seedlings per hill for San-pahtawng1 rice genotype could not replace the crop establishment method using 4 seedlings per hill, as all the values of benefit-cost ratio (B/C ratio) under crop establishment methods using lesser number of seedling per hill were less than 1 which means that any feasibilities for investment in transplanted rice production were in a loss. Tongaram (2004) and Bangchaud (2001) stated that most of investors would select a project that could gain the net profits in the shortest period based on the value of B/C ratio. The value of B/C ratio determines the feasibility of the investment: more than 1 could mean that the project is more feasible; equal to 1 could mean that the project is still feasible; whereas the value is less than 1 could mean that it is not feasible for investment because of a possible loss.

Table 1. Plant height (cm/plant).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	109.50a≠	108.78a	110.97a	109.58a	109.71a*
San-pah-tawng1	104.25a	105.70a	105.52a	105.72a	105.30b
Mean	106.88aδ	107.24a	108.25a	107.65a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 2. Panicle number per square meter (no./m^2).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	180.00a≠	172.00a	191.00a	207.00a	187.50a*
San-pah-tawng1	190.00a	200.00a	206.00a	206.00a	200.50a
Mean	185.00aδ	186.00a	198.50a	206.50a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 3. Shoot dry weight per square meter (g/m^2).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	1,203.10a≠	1,077.40a	1,218.20a	1,305.40a	1,201.03a*
San-pah-tawng1	1,182.00a	1,290.20a	1,317.70a	1,350.60a	1,285.13a
Mean	1,192.55aδ	1183.80a	1,267.95a	1,328.00a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 4. Percent filled grain number (%).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	92.00a≠	89.50a	90.75a	90.50a	90.69a*
San-pah-tawng1	89.25a	89.75a	90.75a	90.50a	90.06a
Mean	90.63aδ	89.63a	90.75a	90.50a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 5. Filled grain number per panicle (no./panicle).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	111.25a≠	94.00a	95.75a	92.50a	98.38a*
San-pah-tawng1	77.00a	84.25a	83.00a	85.50a	82.44b
Mean	94.13aδ	89.13a	89.38a	89.00a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).

δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 6. 1,000-grain weight (g).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	28.35a≠	28.35a	27.42a	28.10a	28.06b*
San-pah-tawng1	28.60a	29.10a	29.45a	28.95a	29.03a
Mean	28.48aδ	28.73a	28.44a	28.53a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 7. Harvest index (dimensionless).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	0.47a≠	0.42ab	0.41ab	0.41ab	0.43a*
San-pah-tawng1	0.35b	0.37ab	0.38ab	0.37ab	0.37b
Mean	0.41aδ	0.40a	0.40a	0.39a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).
δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)
≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 8. Grain yield (t/ha).

Genotype (G)	Crop Establishment Method (CE)				Mean
	1 seedling/hill	2 seedlings/hill	3 seedlings/hill	4 seedlings/hill	
RD14	6.19a≠	5.74a	5.68ab	5.93a	5.89a*
San-pah-tawng1	4.25b	4.92ab	5.28ab	5.39ab	4.96b
Mean	5.22aδ	5.33a	5.48a	5.66a	

*in the column of G means with the same letter is not significantly different at 0.05 probability level (DMRT).

δ in the row of CE means with the same letter is not significantly different at 0.05 probability level (DMRT)

≠in the table of CE X G means with the same letter is not significantly different at 0.05 probability level (DMRT).

Table 9. Simple benefits and costs (production economics) of 2 rice genotypes grown in transplanted fields using 1, 2, 3, and 4 seedling(s) per hill (baht/hectare/single growing season)**.**

Item	Cost/unit	Unit number	Total (baht/hectare/single growing season)							
			RD14 rice genotype				San-pah-tawngl rice genotype			
			1 seedling /hill	2 seedling s/hill	3 seedling s/hill	4 seedlin gs/hill	1 seedlin gs/hill	2 seedlin gs/hill	3 seedling s/hill	4 seedling s/hill
1. Taxes of the land	44 baht/hectare (ha)/year (1 year = 2 cropping)	1 cropping (dry season) /ha	22	22	22	22	22	22	22	22
2. Seed price for RD14 and San-Pah-Tawngl (seedlings preparation)	40 baht/kg	15-60 kg	600	1,200	1,800	2,400	600	1,200	1,800	2,400
3. Pump rental (5% of gross yield)	-	***	2,785	2,583	2,556	2,668	1,912	2,214	2,376	2,425
4. Diesel for irrigation	4hrs/time/day x 16 times/ha x 6.5liter diesel/4hrs/time x 31 baht/liter diesel	104 liters diesel/ha	3,224	3,224	3,224	3,224	3,224	3,224	3,224	3,224
5. Laborer for irrigation	300 baht/man-day	8 man-days/ha	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
6. Land preparation (hand tractor)	-	-	-	-	-	-	-	-	-	-
6.1 Nursery bed (25 m^2)	-	-	-	-	-	-	-	-	-	-
6.1.1 Laborers for irrigation	300 baht/nursery bed/time	2 times/nursery	600	600	600	600	600	600	600	600
6.2 Transplanted rice fields	-	-	-	-	-	-	-	-	-	
6.2.1 Plowing (inclusive of meal)	1,875 baht/ha	1 time/ha	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750
6.2.2 Land leveling (inclusive of meal)	1,875 baht/ha	1 time/ha	1,875	1,875	1,875	1,875	1,875	1,875	1,875	1,875

Item	Cost/unit	Unit number	Total (baht/hectare/single growing season)							
			RD14 rice genotype				San-pah-tawng1 rice genotype			
			1 seedling /hill	2 seedling s/hill	3 seedling s/hill	4 seedling s/hill	1 seedling s/hill	2 seedlin gs/hill	3 seedling s/hill	4 seedling s/hill
7. Laborers (pulling the seedlings)	300 baht/man-day	6 man-days/ha	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
8. Transplanting	300 baht/man-day	20 man-days/ha	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
9. Fertilizer cost	-	-	-	-	-	-	-	-	-	-
9.1 Chemical fertilizer (15-15-15)	1,150 baht/sack (50 kg/sack)	333.32 kg/ha	7,666	7,666	7,666	7,666	7,666	7,666	7,666	7,666
9.2 Urea [CO(NH2)2] (46-0-0)	1,250 baht/sack (50 kg/sack)	130.38 kg/ha	3,260	3,260	3,260	3,260	3,260	3,260	3,260	3,260
10.1 Basal fertilizer application	300 baht/man-day	2 man-days	600	600	600	600	600	600	600	600
10.2 First N topdressing	300 baht/man-day	2 man-days	600	600	600	600	600	600	600	600
10.3 Second N topdressing	300 baht/man-day	2 man-days	600	600	600	600	600	600	600	600
11. Chemical cost	-	-	-	-	-	-	-	-	-	-
11.1 Herbicide (weed killer)	350 baht/liter of chemical	1 liter of chemical/ha	350	350	350	350	350	350	350	350
12. Chemical application	-	-	-	-	-	-	-	-	-	-
12.1 Herbicide spraying	300 baht/man-day	3 man-days/ha	900	900	900	900	900	900	900	900
13. Hand weeding at vegetative stage	300 baht/man-day	5 man-days/ha	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
14. Hand weeding at reproductive stage	300 baht/man-day	5 man-days/ha	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
15. Harvesting using machinery (exclusive of meal)	3,750 baht/ha	1 ha	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750
16. Packaging (sack cost)	5 baht/sack (50 kg/sack)	***	619	574	568	593	425	492	528	539

Item	Cost/unit	Unit number	Total(baht/hectare/single growing season)							
			RD14 rice genotype				San-pah-tawngl rice genotype			
			1 seedling /hill	2 seedling s/hill	3 seedling s/hill	4 seedling s/hill	1 seedling s/hill	2 seedlin gs/hill	3 seedling s/hill	4 seedling s/hill
17. Transportation of the grain from farm to house	10 baht/sack of hulled rice (50kg/sack)	***	1,238	1,148	1,138	1,186	850	984	1,056	1,078
18. Seed drying (sun-dry)	-	-	-	-	-	-	-	-	-	-
18.1 First grain drying	7 baht/sack of hulled rice (50 kg/sack)	***	867	804	795	830	595	689	739	755
18.2 Second grain drying	7 baht/sack of hulled rice	***	867	804	795	830	595	689	739	755
Gross costs/ha basis (1)	-	-	47,373	47,510	48,049	48,904	45,374	46,665	47,635	48,349
Gross benefits/ha basis (2)	9 baht/kg of hulled rice at 14%MC	***	55,710	51,660	51,120	53,370	38,250	44,280	47,520	48,510
Net profit or net loss/ha basis = (2) – (1)	-	-	8,337	4,150	3,071	4,466	-7,124	-2,385	-115	161
Benefit/Cost ratio = (2) ÷ (1)	-	-	1.17	1.08	1.06	1.09	0.84	0.94	0.99	1.00

*** Gross yields of RD14 and San-Pah-Tawngl rice genotypes at 14%MC in transplanted fields using 1, 2, 3, and 4 seedling (s) per hill were 6.19, 5.74, 5.68, 5.93, 4.25, 4.92, 5.28, and 5.39 t/ha, respectively. Baht is a Thai currency. Where; the 31.98 baht is equivalent to 1 USD on July 31, 2014 (X-rates. 2014).

Conclusion

RD14 rice genotype was significantly taller than San-pah-tawng1 rice genotype. Grain yield of RD14 rice genotype was significantly higher than San-pah-tawng1 rice genotype; mainly due to RD14 rice genotype had higher filled grain number per panicle and harvest index. Grain yield, however, was affected by crop establishment method and rice genotype as only the grain yield of RD14 rice genotype under crop establishment method using 1 seedling/hill was appreciably higher than the controlled treatment (crop establishment method using 4 seedlings/hill). The high costs of production were found to be from the two rice genotypes grown under crop establishment methods using 4 seedlings per hill; mainly due to the higher use of seed rate per hectare for seedling preparation raising the cost of production as compared to the other crop establishment methods of 2 rice genotypes using lesser number of seedlings per hill. The seeds' cost for seedling preparation for RD14 rice genotype under crop establishment methods using 1 seedling/hill could be saved by about 75% compared to that under crop establishment method using 4 seedlings per hill. The net profit derived from RD14 rice genotype grown under crop establishment methods using 1 seedling/hill was considerably higher than that of the controlled treatment by 46%. Therefore, the crop establishment method using 1 seedling/hill for RD14 rice genotype was the most feasible for investment in transplanted rice production indicated by the highest value of benefit-cost ratio (B/C ratio is 1.17) compared to the rest of treatments.

Acknowledgement

The authors were highly thankful to Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) for financial support, and to Assoc. Prof. Dr. Preeda Boon-long for his guidance and suggestions in this research. They were also highly thankful to Phrae Rice Research Center for rice seeds support and for Mrs. Jiraporn Mongkron who willingly allowed using her fields as the experimental sites.

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