Factors Related to Differences in Rice Yield among Districts in Narathiwat Province, Southern Thailand

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Abstract The objective of this study was to identify the factors related to rice yield differences among the main rice-producing districts in Narathiwat Province, southern Thailand. In Narathiwat Province, about 70% of total rice is produced in three districts; Tak-bai, Bacho and Yi-ngo. Yield survey showed that Yi-ngo district recorded the highest average yield throughout three consecutive years (3.5 t ha⁻¹), followed by the mountain area of the Bacho district (2.7 t ha⁻¹), alluvial area of the Bacho district (2.6 t ha⁻¹), and Tak-bai district (2.2 t ha⁻¹). The yield differences among the districts were not significantly associated with the planting density or fertilizer application level, but were mainly due to the difference in rice varieties. When Colijor and Litmus, the main cultivars in Yi-ngo, were grown in Tak-bai, they produced a higher grain yield than the traditional varieties cultivated in Tak-bai. These findings suggested that if the high-yielding varieties could be introduced to other districts in Narathiwat Province, the average yield in the districts would increase. The soil properties were another determinant of the yield differences among the districts. Though the yield differences were not associated with the soil nitrogen content and soil organic matter content, they were closely correlated with the soil texture. The soil in Yi-ngo contained more sand, compared with the soil in Tak-bai, which was considered to be conducive to a high drainage efficiency.

Key words Acid soil, Cultivar difference, Grain yield, Oryza sativa L., Rice, Thailand

Introduction

The population of rice consumers is increasing at the rate of 1.8% annually, and hence we need to increase rice productivity particularly in Southeast Asia, which is the main rice-producing area in the world. Thailand is the world's leading rice exporter, selling about 4-6 million tons of rice every year, but the average grain yield is as low as 2.2 t ha⁻¹ on a national basis, which is lower than that in other Asian countries7). In Thailand, there are many problem soils for crop cultivation and most of them occur in the southern region of Thailand2). In Narathiwat Province, which is located in the southernmost part of Thailand, acid soil is a serious problem, and hence rice cannot be grown in this region without lime application. Along with acid soil, drainage in paddy fields is also a problem for rice cultivation in rainfed lowland ecosystems as in the case of Narathiwat. Besides, low soil fertility is a constraint on rice

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yield there.

In addition to the soil problems, cultivation methods, such as planting density and fertilizer application, significantly affect the grain yield of rice, because, it is considered that it is essential to increase the aboveground biomass accumulation in raking account of the critical nitrogen level in the tropics. Moreover, the adoption of suitable varieties is also important to obtain a higher grain yield in this region.

In a preliminary survey on the grain yield of rice in several rice-producing districts in Narathiwat Province, we observed a large variation in yield among the districts. This prompted us to investigate the factors related to grain yield differences among the main rice-producing districts in Narathiwat Province in order to increase the average rice yield in all the districts of the region.

Materials and Methods

Sites for investigations

Since Tak-bai, Bacho and Yi-ngo are the main rice cultivation districts in Narathiwat Province, producing about 70% of the total rice in the Province, we selected these three districts as sites for the investigations. The district of Bacho was subdivided further into two areas in terms of soil conditions; alluvial soil area, and mountain soil area, resulting in four districts as final sites for the investigations. In each district, five farms were selected randomly for the observation of rice yield and soil characteristics. The studies were conducted for three consecutive years from 1996 to 1998.

Cultivation conditions

Since the soil of Tak-bai was a strong acid sulfate soil, and also in Bacho and Yi-ngo the soil was somehow acid, all the paddy fields selected for the investigations had been amended by the application of lime. Transplanting was performed at the beginning of October in most of the farmers’ fields, and harvesting took place from the end of February to early March depending on the varieties. A planting density of 30 × 30 cm was adopted by 13 farmers in the four districts, while a density of 40 × 40 cm was adopted by 7 farmers explanation for the difference in the planting density was not given by the farmers. Compound fertilizer (16-20-0, N-P-K) was applied at the rate of 125 kg ha⁻¹ to 188 kg ha⁻¹ as basal dressing. No pesticides and herbicides were used.

Determination of grain yield and yield components

At harvest time of each variety, ten hills of rice plants were harvested from each farmer’s field. After the plant materials were air-dried, the grains were removed from the panicle, and used for the determination of the yield and yield components.

Yield trials of identical varieties in different districts

Based on the results of the yield surveys conducted in the first two years, 1996 and 1997, it was considered that the differences in yield between the Yi-ngo district, with the highest yield, and Tak-bai district, with the lowest yield, were mainly due to the difference in the varieties used in each district. Hence, we conducted yield trials for the same varieties in the Yi-ngo and Tak-bai districts to determine whether the yield differences were caused by a difference in the potential yielding ability of the varieties. Two varieties, Colijor and Litmus were selected from Yi-ngo, Pao was selected from the Bacho mountain area, and Luk-daeng was selected from Tak-bai. The yield trials were conducted using these four varieties in the paddy fields of Yi-ngo and Tak-bai during the rainy season from October to February, 1998. Twenty eight days old seedlings were transplanted, and 12.5 kg of chemical compound fertilizer (16-20-0, N-P-K) was applied at the maximum tillering stage at four weeks after transplanting and at the panicle initiation stage. Fourteen hills of each variety were harvested, and the yield and yield components were determined. The plot size was 4 × 3 m for each variety with two replications of a randomized complete block design.

Results

Average grain yield was significantly higher in the Yi-ngo district than in any of the other three districts during the three-year period (Fig. 1). In 1996, the average yield in Yi-ngo exceeded 3.3 t·ha⁻¹, followed by the Bacho mountain area, Bacho alluvial area, and then by Tak-bai where the average yield was 2.7 t·ha⁻¹, 2.2 t·ha⁻¹, 2.1 t·ha⁻¹, respectively. In both 1997 and 1998, the relative yield among the districts showed almost
the same trend as that in 1996 except for the Bacho mountain area in 1997 where the average yield was lower than in the Bacho alluvial area.

Within the same district too, there was a large variation in the yield between the farms particularly in 1996 and 1997, although the yield level in each farm was not constant throughout the different years. The large variation in the yield between the farms in the same district might be partly due to the difference in the technology adopted by the farmers, which, however, tended to change (Fig. 2).

The variation in grain yield among the districts and the farms was significantly associated with the variation in total dry matter production (Fig. 3). In Yi-ngo, obviously, a higher dry matter yield was obtained than in the other districts, suggesting that the high dry matter production rate led to a high yield of rice in the Yi-ngo district. Along with the source capacity expressed as dry matter production rate, the sink capacity should be the other determinant of rice yield. Table 1 shows the trend of the yield components in each district. It was evident that a large
number of panicles per unit land area and also a high percentage of filled grains were the major components for high yield of rice in the Yi-ngo district. It was considered from these results that the high dry matter production rate and efficient partitioning of the dry matter to the panicles were the main causes of the high yield of rice in the Yi-ngo district.

To identify the factors that determine the differences in dry matter yield or grain yield among the districts, cultivation methods, such as planting density, and also soil properties, such as nitrogen and organic matter contents in soil were examined in each farmer's field. Most of the farmers in the four districts in Narathiwat region adopted the planting density of $30 \times 30$ or $40 \times 40$ cm. We could not find any correlation between the planting density and average yield at both district level and individual farm level. Also, no significant relationship was observed in our investigations regarding the rate of fertilizer application at the individual farm level.

As for soil fertility, we determined the nitrogen content and organic matter content of the soil taken from each farm in the four districts (Fig. 4). Average contents of soil nitrogen and organic matter in each district were the highest in Tak-bai, where the dry matter yield and grain yield were the lowest, and the lowest in Yi-ngo where the yield was the highest among the four districts.

These findings show that there was no correlation between the yield and soil fertility in the Narathiwat region. However, we observed that the soil texture may account for the yield differences among the districts (Table 2). Clay content was as low as 2, and 9%, in the Bacho mountain area and Yi-ngo, respectively, whereas as high as 18, and 30% in the Bacho alluvial area, and Tak-bai, respectively. These findings suggest that the drainage efficiency of the soil was high in the Yi-ngo and Bacho mountain districts compared with the Bacho alluvial and Tak-bai districts. This high drainage efficiency was associated with the high yield of rice in the Yi-ngo and Bacho mountain districts. However, the differences in yield between the Yi-ngo and Bacho mountain districts could also be due to other factors than the drainage efficiency. In the Narathiwat region, more than fifteen traditional rice varieties are cultivated. Therefore, the difference in grain yield could be attributed to the difference in the yielding ability of the varieties. Figure 5 shows a list of varieties with a ranking for grain yield. In Tak-bai where the average grain yield was the lowest among the four districts, the number of varieties was limited to only two; Luk-daeng and Jante, while in the other 3 districts, four to five varieties were used. Five varieties with the highest ranking in Fig. 5 were cultivated in the Yi-ngo and Bacho mountain districts where the average yield was higher than in the other two districts. It was considered, therefore, that the differences in the yield level among the districts were closely associated with the variety of rice used in each
Table 1. Comparison of yield components of rice in four districts of Narathiwat.

<table>
<thead>
<tr>
<th>Year</th>
<th>District</th>
<th>No. of panicles (m²⁻¹)</th>
<th>No. of grains (panicle⁻¹)</th>
<th>No. of grains (m²⁻¹)</th>
<th>1000-grain wt. (g)</th>
<th>Filled grains (%)</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>Tak-bai</td>
<td>78.7 b</td>
<td>191 ns</td>
<td>14996 ns</td>
<td>22.3 ns</td>
<td>62.3 c</td>
<td>0.28 c</td>
</tr>
<tr>
<td></td>
<td>Bacho (alluvial area)</td>
<td>81.2 ab</td>
<td>190 ns</td>
<td>15384 ns</td>
<td>23.2 ns</td>
<td>60.5 c</td>
<td>0.30 bc</td>
</tr>
<tr>
<td></td>
<td>Bacho (mountain area)</td>
<td>77.9 b</td>
<td>193 ns</td>
<td>14878 ns</td>
<td>23.8 ns</td>
<td>73.5 b</td>
<td>0.33 ab</td>
</tr>
<tr>
<td></td>
<td>Yi-ngo</td>
<td>96.0 a</td>
<td>168 ns</td>
<td>16162 ns</td>
<td>24.0 ns</td>
<td>84.5 a</td>
<td>0.35 a</td>
</tr>
<tr>
<td>1997</td>
<td>Tak-bai</td>
<td>74.7 b</td>
<td>217 ns</td>
<td>15681 b</td>
<td>21.3 b</td>
<td>58.7 c</td>
<td>0.33 c</td>
</tr>
<tr>
<td></td>
<td>Bacho (alluvial area)</td>
<td>77.9 b</td>
<td>227 ns</td>
<td>17629 ab</td>
<td>19.5 c</td>
<td>74.2 a</td>
<td>0.48 a</td>
</tr>
<tr>
<td></td>
<td>Bacho (mountain area)</td>
<td>69.4 b</td>
<td>228 ns</td>
<td>15857 b</td>
<td>21.2 b</td>
<td>65.8 b</td>
<td>0.43 b</td>
</tr>
<tr>
<td></td>
<td>Yi-ngo</td>
<td>90.8 a</td>
<td>211 ns</td>
<td>19095 a</td>
<td>23.9 a</td>
<td>71.7 ab</td>
<td>0.39 bc</td>
</tr>
<tr>
<td>1998</td>
<td>Tak-bai</td>
<td>82.5 b</td>
<td>194 b</td>
<td>15861 b</td>
<td>22.1 c</td>
<td>76.7 b</td>
<td>0.46 ns</td>
</tr>
<tr>
<td></td>
<td>Bacho (alluvial area)</td>
<td>88.5 ab</td>
<td>204 b</td>
<td>17746 a</td>
<td>23.6 b</td>
<td>72.8 c</td>
<td>0.46 ns</td>
</tr>
<tr>
<td></td>
<td>Bacho (mountain area)</td>
<td>95.1 a</td>
<td>189 b</td>
<td>16951 ab</td>
<td>23.2 b</td>
<td>81.8 a</td>
<td>0.48 ns</td>
</tr>
<tr>
<td></td>
<td>Yi-ngo</td>
<td>80.8 b</td>
<td>232 a</td>
<td>17973 a</td>
<td>25.3 a</td>
<td>81.0 a</td>
<td>0.47 ns</td>
</tr>
</tbody>
</table>

Ns: not significant.
Same letters indicate that no significant difference at probability level 0.05 was observed.

Fig. 4. Contents of organic matter (A) and total nitrogen (B) in the soil of each district. Columns with different letters for each year indicate significant difference at 5% level.

Table 2. Soil texture in four districts.

<table>
<thead>
<tr>
<th>District</th>
<th>Particle-size distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clay</td>
</tr>
<tr>
<td>Tak-bai</td>
<td>30</td>
</tr>
<tr>
<td>Bacho (alluvial area)</td>
<td>18</td>
</tr>
<tr>
<td>Bacho (mountain area)</td>
<td>2</td>
</tr>
<tr>
<td>Yi-ngo</td>
<td>9</td>
</tr>
</tbody>
</table>

Each value was the average of paddy fields in five farms in each district.

district, and moreover, it was assumed that Litmus and Colijor, the varieties cultivated by the farmers in Yi-ngo contributed to the high yield of rice in the Yi-ngo district.

In order to confirm the above assumption, Litmus and Colijor from Yi-ngo, Pao from the Bacho mountain area, and Luk-daeng from Tak-bai were grown both in Yi-ngo and Tak-bai. Litmus and Colijor showed a higher grain yield than the other two varieties not only in Yi-ngo but also in Tak-bai (Fig. 6). In Tak-bai, Colijor showed a significantly (P<0.05) high yield of 3.2 t·ha⁻¹ that was about 40% higher than the yield of Luk-daeng, a traditional variety used in Tak-bai. We plotted the grain yield against the dry matter yield of individual plants harvested in Yi-ngo and Tak-bai for each of the four varieties. The grain yield was significantly (P<0.01)
Variety

Fig. 5. Variation in rice yield of cultivated varieties in four districts. The number in the column for each variety indicates the number of farmers who adopted the variety.

Fig. 6. Difference in rice yield of four rice varieties in Yi-ngo and Tak-bai. Columns with different letters for each site indicate significant difference at 5% level.

correlated with the dry matter yield in the case of Colijor, Litmus and Pao, which were assumed to have high yield potentials, while in Luk-daeng no significant correlation was observed (Fig. 7). Moreover, the dry matter yield reached a value of 1,200 g per m² in the Colijor variety, while Luk-daeng produced only 610 g of dry matter per m² which was about half the value of that of Colijor.

Discussion

We observed a large variation in the average yield among the districts and also among individual farms in the same district. It was reported by YING et al. (1998) that yield potential of rice in the tropics depends mainly on the ability to increase the rate of dry matter production and the size of sink organs. In this connection, our investigation indicates that a large number of panicles per unit land area and high percentage of filled grains were the major components for the high yield of rice in the Yi-ngo district. Although the factors related to the dry matter yield, may include the planting density and the rate of fertilizer application, no correlation was detected between the yield and planting density or amount of applied fertilizer throughout the four districts. Wu et al. have recently reported that the grain yield was not always significantly affected by the plant density.

Since it was suggested in this study that the differences in the grain yield among the districts were due to the difference in the varieties, yield trials were conducted in Yi-ngo and Tak-bai using the same varieties. Colijor and Litmus have a high grain yield in Yi-ngo and also in Tak-bai, indicating that if the high-yielding varieties such as Litmus or Colijor could be introduced to Tak-bai, the average
yield level in Tak-bai would increase. The fact that the farmers of Tak-bai are using only two traditional varieties, Luk-daeng and Jante, could be attributed to the lack of information transfer and also to the lack of efficient technology extension network.

The soil properties markedly affected the differences in rice yield among the districts. However, we could not find any association between the grain yield and the fertilizer application level. Cassman et al. reported that there was no relationship between nitrogen use and grain yield in farmers’ paddy fields in the tropical region. The pH of soil may also be an important factor related to the differences in yield among the districts in the Narathiwat region. Attanandana et al. reported that liming exerted a beneficial effect on rice yield, and moreover, Khan et al. reported that soil pH amendment by leaching, application of basic slag and MnO₂, to acid sulfate soils in a pot experiment led to a grain yield increase of 500–900%. In Tak-bai where the soil of the paddy fields is a strong acid sulfate soil, rice was grown with the application of lime, and the pH of some paddy fields in Tak-bai was higher than in other districts of Narathiwat. Nevertheless, the rice yield in Tak-bai was still low compared with that in other districts. This fact suggests that the soil pH is not the major constraint on rice yield in Narathiwat Province, and that variety and soil texture are the main limiting factors to the grain yield of rice in this region. Other social and natural factors may determine the differences in yield among the districts in Narathiwat Province, such as the extent of

Fig. 7. Relationship between total dry matter weight and rice yield of four rice varieties.

; Yi-ngo, ; Tak-bai.
intensification of field management, and changes in the climatic and soil conditions due to geographic differences.

The results of this study suggested that the introduction of the high-yielding varieties used in Yi-ngo to other districts may improve the yield in the Narathiwat region. It is thus recommended that an efficient system for technology and information transfer should be developed for the improvement of rice yield in the Narathiwat region.

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