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# ADAPTATION OF RICE GENOTYPES TO DIVERSE RAINFED LOWLAND PADDY CONDITIONS

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## SUMMARY

Climate change is the main hindrance which affects the rice production especially under rainfed conditions. Rice production is also distressed by the variability and fluctuation in frequency and timings of rainfall. The evaluation of 12 rice (*Oryza sativa* L.) genotypes was carried out in diverse environments (locations, planting times, and paddy conditions) under rainfed lowland conditions in Northeast Thailand. The experiment was conducted at different number of locations i.e., two, three and ten locations were used during 2013, 2014 and 2015, respectively. Two toposequences (top and bottom) were mostly used, however, at locations of Huatapan and Sumrong the toposequence were three (top, middle and bottom) with three planting times, comprising a total of 19 plots throughout Northeast Thailand. The experiment was laid out in a randomized complete block design (RCBD) with single replication. Therefore, genotypes, planting times and toposequences, were treated as replications for analyzing the differences among locations. Significant differences were observed among the rice genotypes, locations, planting times, and toposequences. Based on rice genotypes and grain yield in different growing environments, the cluster analysis was conducted. Six groups of growing environments and three groups of genotypes were identified. Relationship between environments and grain yield of genotypes showed that two groups of the genotypes were identified which were having highest yield potential with photoperiod sensitivity than insensitivite genotypes. Results further suggested that under unpredictable climatic conditions like rainfed lowland rice in Northeast Thailand, the photoperiod sensitivity would be recommended. Furthermore, the selection based on diverse environmental conditions (locations, planting times, and toposequences) was found highly different in each farmer field; however, was promising in target area selection.

**Key words:** Multi-environment trials, planting times, toposequences, photoperiod sensitivity, rainfed lowland rice conditions, *Oryza sativa* L.

**Key findings:** Rice genotypes with photoperiod sensitivity were found suitable for diverse rainfed lowland rice conditions in Northeast Thailand. However, the genotypes revealed significant differences for grain yield.

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## INTRODUCTION

Climate change affects the agriculture through direct and indirect effects on crops, soil, livestock and pests, and eventually the global food security (FAO, 2018). Identification of varietal characteristics those are suited to changing environment should be a strategy for solving problems associated with climate change. Rice (*Oryza sativa* L.) production under rainfed conditions is a complex system, and it is vulnerable to climate change and the soil environment. Several environmental factors i.e., toposequence, rainfall, air temperature, solar radiation, wind direction and wind speed directly affect the growth and yield of rice (Yoshida, 1981; Inthavong *et al*., 2012). The use of suitable rice cultivars should be a priority that leads to stable and optimum rice grain yield under rainfed conditions.

In North-eastern region of Thailand, rice is grown on the largest area which is about 62% of the country's total rice growing area (OAE, 2019). In this region, majority of the rice growing area is under lowland rainfed which accounted for more than 80% of the total growing area in that region. Overall, the rice production in this region is low and fluctuates year to year ranging between 2.1 t $ha^{-1}$ (OAE, 2019). Differences in soil texture and fertility have been reported and soils in upper paddies are lighter in texture and poorer in fertility than those of lower paddies (Homma *et al*., 2007). Higher clay soil content contributes to higher grain yield due to the prolong stay of standing water in the paddies (Homma *et al*., 2007; Tsubo *et al*., 2007).

In rain-fed rice zone, the use of cultivars with appropriate flowering duration is very important and has major role in improving rice production. Environmental stresses, particularly drought is mostly occurs during the growing period, and is considered a major factor influencing the variation in rainfed lowland rice yield (Wade *et al*., 1999; Ly *et al*., 2016). There were three types of drought depending on its timing of occurrence; early, intermittent and terminal drought (Kamoshita *et al*., 2008). Droughts significantly affect the plant growth and bring larger variation in soil water level during the growth period in Northeast Thailand (Fukai *et al*., 1999; Bell and Seng, 2004). Therefore, for wider adaptation, the rice genotypes should be tested under different environments throughout the region (Cooper and DeLacy, 1994).

In order to improve the crop performance, it is necessary to know the response of genotypes to the target environment (Cooper and Byth, 1996). In breeding programs, the major task is to identify the promising lines and cultivar development for the specified environment through multi-environmental trials. Differential response of cultivars or group of genotype (G) to varied environments (E) and genotype by environment (G × E) interaction effects are needed to probe the potential rice genotypes (Cooper *et al*., 1999; Atlin, 2001; Windhausen *et al*., 2012). Currently, the genotype, G × E interaction (GEI) and GGE-biplot methods (Yan *et al*., 2001) have become very popular in determination of superior genotypes for specific environments (Navabi *et al*., 2006; Roozeboom *et al*., 2008; Mohammadi *et al*., 2010; Pimsaen *et al*., 2010).

So far, the information about the response of appropriate paddy positions and planting time for photoperiod sensitive and insensitive rice cultivars has been limited in the past findings. Therefore, the aim of this study was to investigate the responses of planting and flowering time, rice genotypes to photoperiod and grain yield with suitable adaptation to diverse paddy conditions under rainfed lowland rice. This information could help in identification of suitable and superior rice genotypes and planting time for specific paddy conditions to enhance the rice production.

**Table 1.** Rice cultivars planted during 2013 to 2015 and characteristic responses to photoperiod and flowering time.

| Years | Cultivars | Sensitivity to photoperiod | Flowering date / DTF |
|---|---|---|---|
| 2013 | KDML-105 | Sensitive | Oct - 20 |
| | RD-6 | Sensitive | Oct - 21 |
| | RD-12 | Sensitive | Oct - 15 |
| | RD-33 | Insensitive | 100 days |
| | SKN | Insensitive | 98 days |
| | SPT-1 | Insensitive | 100 days |
| 2014 | KDML-105 | Sensitive | Oct - 20 |
| | RD-6 | Sensitive | Oct - 21 |
| | RD-12 | Sensitive | Oct -15 |
| | RD-33 | Insensitive | 100 days |
| | SKN | Insensitive | 98 days |
| | SPT-1 | Insensitive | 100 days |
| 2015 | KDML-105 | Sensitive | Oct - 20 |
| | RD-6 | Sensitive | Oct - 21 |
| | RD-12 | Sensitive | Oct - 15 |
| | RD-15 | Sensitive | Oct - 10 |
| | RD-18 | Sensitive | Oct - 21 |
| | Y329-UBN-13 | Sensitive | Oct - 23 |
| | IRUBN040041-B-B-5 | Sensitive | Oct - 23 |
| | IRUBN050035-B-7-B | Sensitive | Oct - 23 |
| | IRUBN050032-B-1-B | Sensitive | Oct - 23 |

Note: Flowering date is for photoperiod sensitivity and (DTF) days to flowering is for photoperiod insensitivity genotypes.

## MATERIALS AND METHODS

### Plant material

Twelve rice (*Oryza sativa* L.) diverse genotypes comprising KDML-105 (Khao Dawk Mali 105), RD-6, RD-15, RD-12, RD-18, RD-33, SKN (Sakon Nakhon), SPT-1 (San PahTawng1), Y329-UBN-13, IRUBN040041-B-B-5, IRUBN050035-B-7-B, and IRUBN050032-B-1-B were studied for three consecutive years during 2013, 2014 and 2015. Among 12 genotypes, three were insensitive, while nine other genotypes were sensitive to photoperiod (Table 1). However, the genotypes used for studies were varied in number during different years i.e., six genotypes (KDML-105, RD-6, SPT-1, RD-12, SKN, and RD-33) were used during 2013 and 2014, and nine other genotypes (having three genotypes in common with above group of six genotypes used during 2013 and 2014) were used during 2015 (KDML-105, RD-6, RD-12, RD-15, RD-18, Y329-UBN-13, IRUBN040041-B-B-5, IRUBN050035-B-7-B, and IRUBN050032-B-1-B).

### Experimental sites and paddy positions

All the experiments were carried out during three consecutive years i.e., 2013, 2014, and 2015 under rainfed lowland conditions on the farmer fields in Northeast Thailand. The number of locations, toposequences and rice genotypes used during each year are shown in Table 2. During 2013, the experiments were conducted at two locations with three toposequences *viz*., top, middle and bottom paddies, three and ten locations were used during 2014 and 2015, respectively with two toposequences i.e., top and middle paddies. The experimental sites with different paddy positions (top, middle and bottom) were scattered throughout Northeast, Thailand. In total, the nineteen experimental fields were maintained during three years.

For three different plantings, the rice seedling nurseries were developed based on farmer practice at all the sites. The first planting was made before the farmer practice, second was farmer practice, and the third planting was after farmer practice with 1/2 weeks intervals. All plots were laid out in a simple randomized with single replication at each location with plot sizes of 3 × 5 $m^2$. Planting methods includes transplanting at 25 × 25 $cm^2$ spacing or the direct seeding method, following farmer practices at each site. Fertilizer was applied basally at rate of 25:31.3 kg NP $ha^{-1}$, and subsequent 14.4 kg N $ha^{-1}$ at 60 days after planting.

### Data collection

Days to flowering were estimated by visual observation and days counted from planting to the day when 50% of plants gain the flowering in each plot. Grain yield was harvested at maturity in an area of 2 × 4 $m^2$. Grain moisture content was reduced by air drying before grain yield determination.

### Data analysis

The simple randomized plot design was used with single replication, and toposequences, planting times and genotypes were treated as replication for analysis to test the difference among locations. Similarly, for testing these factors i.e., toposequences, locations, planting times and

**Table 2.** Locations, toposequences and rice genotypes used in present studies, mean annual rainfall across three years (2013 to 2015) and soil types.

| No | Locations | Toposequences | KDML-105 | RD-6 | RD-12 | RD-15 | SPT-1 | RD-33 | SNK | RD-18 | Y329 | B41 | B35 | B32 | Rainfall (mm) | Soil type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Borabue | Top | 2 | 2 | 1 | 1 | 1 | 1 | 1 |  |  | 1 | 1 | 1 | 806 | Sand |
|  |  | Bottom | 2 | 2 | 1 | 1 | 1 | 1 | 1 |  | 1 | 1 | 1 | 1 | 806 | Sand |
| 2 | Chomphra | Top | 1 | 1 |  | 1 |  |  |  |  | 1 | 1 | 1 | 1 | 1179 | Loamy sand |
|  |  | Bottom | 1 | 1 |  | 1 |  |  |  |  | 1 | 1 | 1 | 1 | 1179 | Sandy loam |
| 3 | Huataphan | Top | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1210 | Sand |
|  |  | Middle | 1 | 1 | 1 |  | 1 | 1 | 1 |  |  |  |  |  | 1210 | Loamy sand |
|  |  | Bottom | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1210 | Sandy loam |
| 4 | Naklang | Bottom | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 666 | Sandy loam |
| 5 | Nonsang | Bottom | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 557 | Sandy loam |
| 6 | Prathai | Top | 1 | 1 |  | 1 |  |  |  |  | 1 | 1 | 1 | 1 | 855 | Sandy loam |
| 7 | Samrong | Top | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1249 | Loamy sand |
|  |  | Middle | 1 | 1 | 1 |  | 1 | 1 | 1 |  |  |  |  |  | 1249 | Sand |
|  |  | Bottom | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1249 | Sandy loam |
| 8 | Siwilai | Top | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1707 | Sandy loam |
|  |  | Bottom | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1707 | Sandy loam |
| 9 | Wanonniwat | Top | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1292 | Sandy clay loam |
|  |  | Bottom | 1 | 1 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1292 | Sandy loam |
| 10 | Yangsisurat | Top | 1 | 1 |  | 1 |  |  |  |  | 1 | 1 | 1 | 1 | 1126 | Sand |
|  |  | Bottom | 1 | 1 |  | 1 |  |  |  |  | 1 | 1 | 1 | 1 | 1126 | Loamy sand |

Note: 1, 2 and 3 indicated number of years for rice genotypes were used in each location and toposequence, (1) year 2015, except SPT-1, RD-33 and SKN were used in 2014, (2) years 2013 and 2014, except at Borabue KDML-105 and RD-6 were used in year 2014 and 2015, (3) year 2013 to 2015. Y329: Y329-UBN-13, B41: IRUBN040041-B-B-8, B35: IRUBN050035-B-7-B and B32: IRUBN050032-B-1-B genotypes, while others three factors were treated as replications. Unbalance data analysis following the randomized plot design were used. In each location and planting time of each trial, the analysis of variance (ANOVA) and the least significant difference (LSD) were tested at 5% probability. Cluster analysis expanded by Euclidean distance and grouping of genotypes or environment types into clusters were accomplished following Ward's method (1963). For grown environments, the grain yield in 19 experimental plots was used to obtain the average grain yield across locations in each genotype for grouping of genotypes.

## RESULTS

### Effect of environments on days to flowering and grain yield

During 2013 to 2015, the experimental plots were grown at 10 locations in main rice production area in Northeast Thailand. There was a significant variation in rainfall across locations and years (Table 2). The data on days to 50% flowering and grain yield across locations, planting times and toposequences is shown in Table 3. These three components i.e., locations, planting times and toposequences revealed significant differences for days to flowering, while for grain yield the locations were only found with significant variations.

The planting time and response of rice genotypes were important, especially under rainfed conditions. The early planting resulted in more days to flowering than late planting. However, the grain yield was not significantly different among the three planting times. On the other hand, the days to flowering of three different planting times were highly significant with long duration of early planting than late planting (Table 3). Most of the studied rice genotypes were photoperiod sensitive in which flowering occurs in the same time of year due to specific day length for inducing panicle initiation.

The toposequence revealed significant effect on days to flowering and top paddy position took more days to flowering as compared to bottom toposequence (Table 3). The differences among toposequences were also affected by rainfall and the water level at each location and soil type. Differences in soil types resulted in the difference in water holding capacity. Soil under bottom toposequence was mostly sandy loam with increased water holding capacity than sandy soil in upper fields (Table 2). Relationship among the locations, mean annual rainfall and grain yield across three years (2013, 2014 and 2015) was constructed in Figure 1. There was a positive trend, however, the relationship was slightly weak ($r = 0.55$). Results suggested that the grain yield was might associated with the frequency of rainfall.

Among locations, the average highest grain yield (4538 kg ha$^{-1}$) was obtained at location Siwilai whereas the site Nonsang produced the lowest grain yield (1888 kg ha$^{-1}$) with mean yield of 2926 kg ha$^{-1}$ across three years. Between two groups of genotypes with photoperiod sensitivity and insensitivity, the differences in grain yield under different toposequences and planting times were in the same trend, and the grain yield was higher under bottom than top paddies and in the second planting time than other two planting times. However, overall the mean grain yield

**Table 3.** Mean grain yield and day to flowering in each location, planting time, toposequence and genotypes across three years (2013 to 2015).

| Environments and genotypes | Locations | Days to flowering (days) | Grain yield (kg ha$^{-1}$) |
|---|---|---|---|
| Locations | Samrong | 123 b | 2124 e |
| | Huataphan | 120 b | 2639 d |
| | Borabue | 111 c | 2304 e |
| | Yangsisurat | 111 c | 3021 c |
| | Prathai | 101 d | 2936 cd |
| | Chomphra | 133 a | 2196 e |
| | Wanonniwat | 128 a | 4137 b |
| | Siwilai | 130 a | 4538 a |
| | Naklang | 107 cd | 3475 c |
| | Nonsang | 122 b | 1888 e |
| | Means | 119 | 2926 |
| | F-test | ** | ** |
| | CV(%) | 10.15 | 33.89 |
| Planting times | Planting date 1 | 133 a | 2923 |
| | Planting date 2 | 123 b | 3022 |
| | Planting date 3 | 112 c | 3000 |
| | Means | 122 | 2982 |
| | F-test | ** | ns |
| | CV(%) | 9.33 | 14.73 |
| Toposequences | Top | 129 a | 2575 |
| | Middle | 119 b | 2689 |
| | Bottom | 108 c | 2678 |
| | Means | 119 | 2647 |
| | F-test | ** | ns |
| | CV(%) | 11.75 | 47.43 |
| Genotypes | KDML-105 | 124 b | 2853 b |
| | RD-6 | 123 b | 3193 a |
| | RD-12 | 113 d | 2794 b |
| | RD-15 | 117 c | 2700 bc |
| | RD-18 | 123 b | 3185 a |
| | RD-33 | 102 e | 2679 bc |
| | SKN | 101 e | 2481 c |
| | SPT-1 | 109 d | 2832 b |
| | Y329-UBN-13 | 129 a | 2971 ab |
| | IRUBN040041-B-B-5 | 128 a | 3080 ab |
| | IRUBN050035-B-7-B | 128 a | 3158 a |
| | IRUBN050032-B-1-B | 128 a | 3186 a |
| | Means | 119 | 2926 |
| | F-test | ** | ** |
| | CV(%) | 10.2 | 33.9 |

** = significant different at $P < 0.01$, ns = not significant different. The different letter after number are significant different within column in each trait.

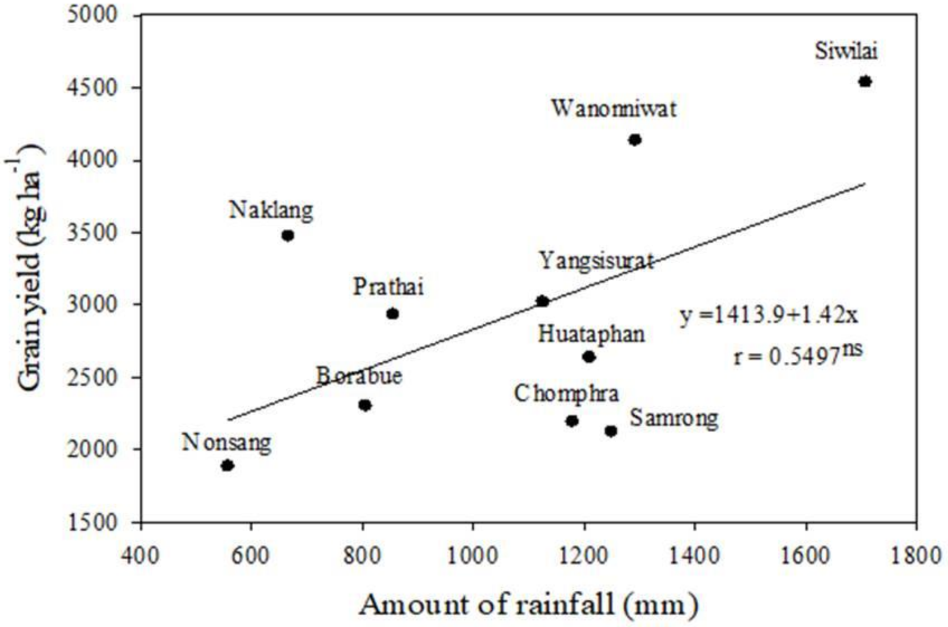

**Figure 1.** Relationship between mean frequency of rainfall across three years and grain yield in each location.
ns = not significant different

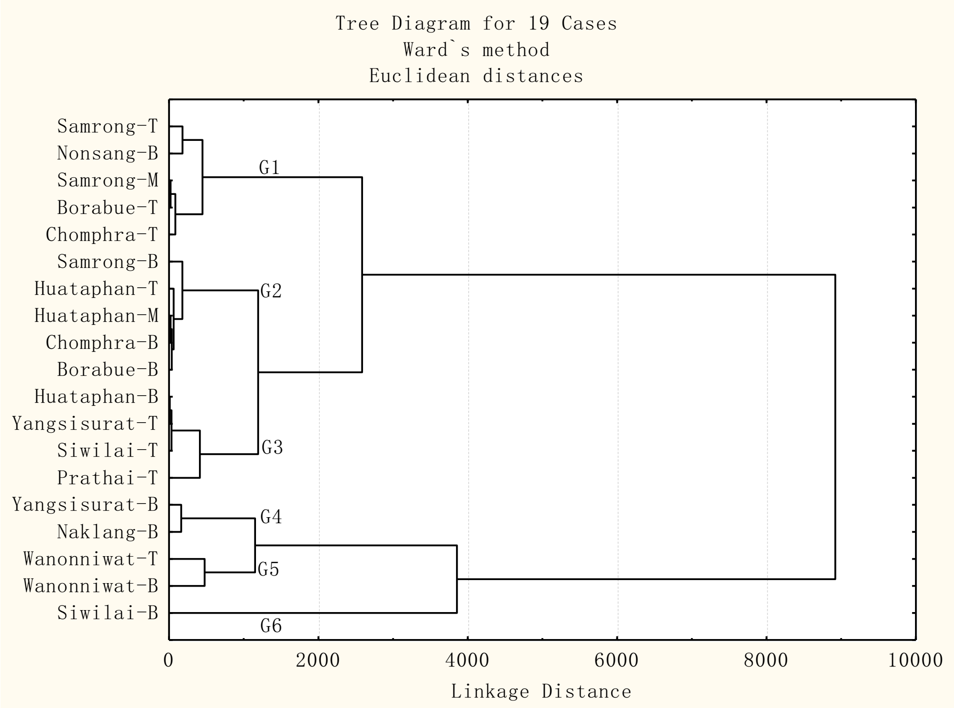

**Figure 2.** Grouping of 19 growing environments into six clusters group by Ward's method (divided at 2000 linkage distance).

for the group of rice genotypes with photoperiod sensitivity was higher than insensitive rice genotypes.

## Genotype differences for days to flowering and grain yield

Genotypes enunciated the significant variations for days to 50% flowering and grain yield. Days to 50 flowering varied from 101 to 129 days with mean of 119 days. On average, the genotype Y329-UBN-13 took more days to flowering, while SKN was observed with minimum number of days. It was also observed that the genotypes with insensitivity to photoperiod took less days to flowering (101 to 109) than sensitive genotypes (113 to 129 days). For grain yield, the genotype RD-6 was leading with highest grain (3193 kg ha$^{-1}$), whereas genotype SKN showed the lowest value for grain yield (2481 kg ha$^{-1}$) (Table 3). Significant positive relationship was observed between the means of days to 50% flowering and grain yield across three years for twelve rice genotypes. The said relationship suggested that the difference in grain yield among the genotypes could be due to the differences in days to flowering, as the genotypes with more days to flowering resulted in higher grain yield which might have longer growth period.

## Grouping of grown environments

Cluster analysis of different grown environments (locations, toposequences and planting times) was conducted using grain yield of 19 experimental plots under 10 locations and three toposequences. Six groups of grown environments were identified (Figure 2). Grain yield and rainfall frequency for individual plot and group mean were shown in Table 4. Results revealed that environment group six with one genotype at Siwilai (bottom) had the leading grain yield (6483 kg ha$^{-1}$). However, the group one consisted of Samrong (top and middle paddy positions), Borabue (top position), Chomphra (top position) and Nonsang (bottom position) produced the lowest grain yield (2036 kg ha$^{-1}$). Difference in ranking in mean group of rainfall was also similar to ranking in mean group of grain yield except the group four which consisted of locations i.e., Yangsisurat and Naklang (bottom position), rainfall was as low as 896 mm. Both Yangsisurat and Naklang were located at the bottom position plots which might received the extra rainwater from other upper paddies nearby.

## Genotypes grouping

Among ten genotypes, three groups of genotypes were identified (Figure 3). The group three comprising the genotypes RD-6 and RD-18 and breeding lines (Y329-UBN-13, IRUBN040041-B-B-5, IRUBN050035-B-7-B, and IRUBN050032-B-1-B) responded with higher grain yield (3129 kg ha$^{-1}$) than all other groups (Table 5). It could be noted that all the breeding lines were progeny of genotype RD-6 which were developed for drought tolerance (Monkham *et al*., 2018). Genotypes in group one consisted of genotypes KDML-105, RD-15, and SPT-1, in which two genotypes (KDML-105 and RD-15) were photoperiod sensitivite, while SPT-1 was photo insensitivite. The group one genotypes provided less grain yield than group three but higher than group two.

**Table 4.** Grain yield, days to flowering, mean frequency of rainfall and soil types for each location group.

| Groups | Locations | Toposequences | Days to flowering (days) | Grain yield (kg ha$^{-1}$) | Rainfall (mm) | Soil type |
|---|---|---|---|---|---|---|
| 1 | Samrong | Top | 125 | 1795 | 1249 | Loamy sand |
| | Samrong | Middle | 102 | 2146 | 1249 | Sand |
| | Borabue | Top | 112 | 2166 | 806 | Sand |
| | Chomphra | Top | 139 | 2095 | 1179 | Loamy sand |
| | Nonsang | Bottom | 126 | 1977 | 557 | Sandy loam |
| Means | - | - | 121 | 2036 | 1008 | - |
| 2 | Samrong | Bottom | 122 | 2360 | 1249 | Sandy loam |
| | Huataphan | Top | 120 | 2525 | 1210 | Sand |
| | Huataphan | Middle | 117 | 2484 | 1210 | Loamy sand |
| | Borabue | Bottom | 111 | 2457 | 806 | Sand |
| | Chomphra | Bottom | 139 | 2485 | 1179 | Sandy loam |
| Means | - | - | 122 | 2462 | 1131 | - |
| 3 | Huataphan | Bottom | 118 | 2736 | 1210 | Sandy loam |
| | Yangsisurat | Top | 112 | 2746 | 1126 | Sand |
| | Prathai | Top | 107 | 3030 | 855 | Sandy loam |
| | Siwilai | Top | 136 | 2759 | 1707 | Sandy loam |
| Means | - | - | 118 | 2818 | 1225 | - |
| 4 | Yangsisurat | Bottom | 124 | 3399 | 1126 | Loamy sand |
| | Naklang | Bottom | 112 | 3562 | 666 | Sandy loam |
| Means | - | - | 118 | 3480 | 896 | - |
| 5 | Wanonniwat | Top | 133 | 3978 | 1292 | Sandy clay loam |
| | Wanonniwat | Bottom | 133 | 4456 | 1292 | Sandy loam |
| Means | - | - | 133 | 4217 | 1292 | - |
| 6 | Siwilai | Bottom | 134 | 6483 | 1707 | Sandy loam |
| Means | - | - | 134 | 6483 | 1707 | - |

## Response of rice genotypes to growing environments

Relationships between grain yield of each group of genotypes and environment group were constructed in Figure 4. The relationships were significant for genotypes group one and group three with values $r^2$ values of 0.96 and 0.99, respectively. However, there was no significance response for genotype group two in which both genotypes were photoperiod insensitivite. This might be due to testing of genotypes in said group in only three growing environments. It was further observed that slope of the genotype group three (1.15) was higher than group one (0.72). Result suggested that genotype group three has better response to growing environments than group one.

## DISCUSSION

Multi-location trial is an important forward step in conventional breeding which aims to identify the suitable genotypes under diverse environmental conditions (growing environments) before its release as a new cultivar. Target environment selection, is the key success which requires the wide range of environments for evaluation of the adaptability. In this study, experimental sites were located throughout Northeast Thailand which

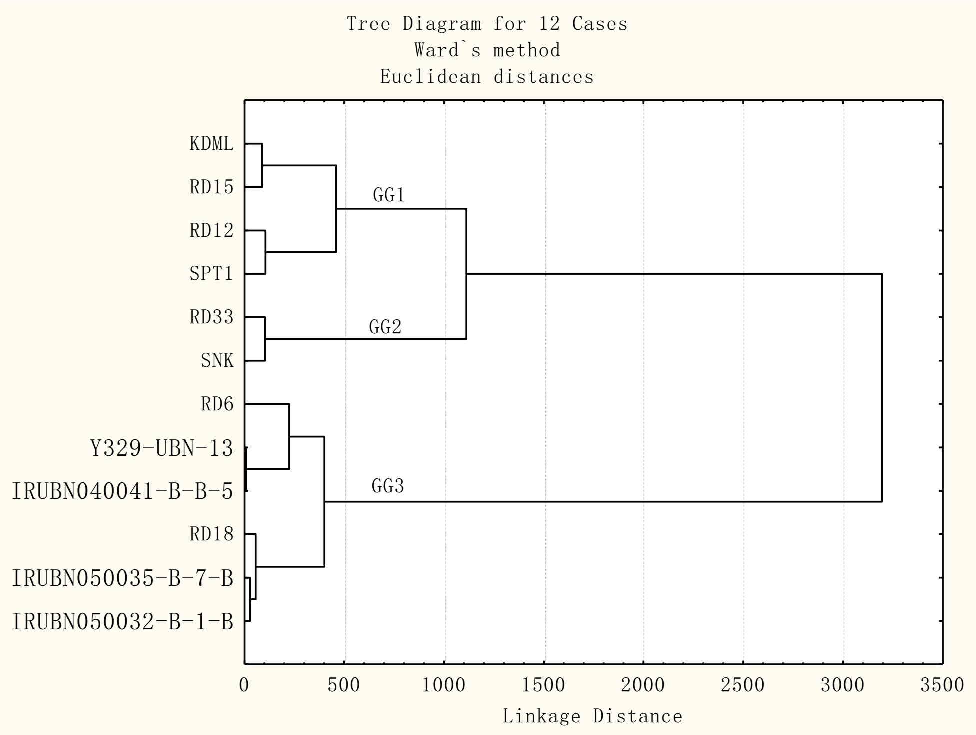

**Figure 3.** Group cluster of twelve genotypes based on days to flowering and grain yield which separated into three genotypes groups by Ward's method (divided at 1000 linkage distance).

**Table 5.** Days to flowering and grain yield for individual genotype and group mean.

| Groups | Genotypes | Days to flowering (days) | Grain yield (kg ha$^{-1}$) |
|---|---|---|---|
| 1 | KDML-105 | 124 | 2853 |
| | RD-12 | 113 | 2794 |
| | RD-15 | 117 | 2700 |
| | SPT-1 | 109 | 2832 |
| Means | - | 116 | 2795 |
| 2 | RD-33 | 102 | 2679 |
| | SNK | 101 | 2481 |
| Means | - | 102 | 2580 |
| 3 | RD-6 | 123 | 3193 |
| | RD-18 | 123 | 3185 |
| | Y329-UBN-13 | 129 | 2971 |
| | IRUBN040041-B-B-5 | 128 | 3080 |
| | IRUBN050035-B-7-B | 128 | 3158 |
| | IRUBN050032-B-1-B | 128 | 3186 |
| Means | - | 127 | 3129 |

is the main rice production area. The evaluation of rice performance should be covered for the target areas and differences in growing environments. In this study, the different planting times were used to evaluate the genotypes response to early and late planting conditions.

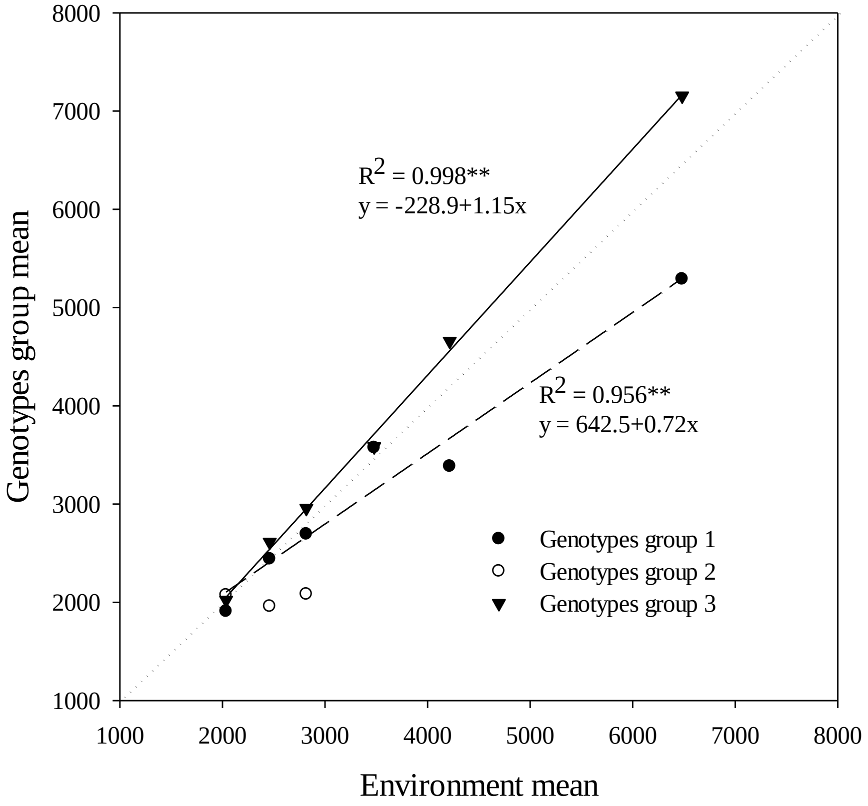

**Figure 4.** Relationships between grain yield of growing environments and genotype groups.
** = significant different at $P < 0.01$.

For evaluation of rice genotypes adaptation, the use of different toposequence should be considered because rainfed lowland rice is often grown in areas with different toposequence in Northeast Thailand. Jongdee *et al*. (2006) and Tsubo *et al*. (2006) have classified that high positions were drought prone environments in lowland rice conditions. Under rainfed lowland condition, the time of planting can be varied based on the onset of rainy season which varies across locations and years in *Oryza sativa* L. (Amarasingha *et al*., 2014; Lar *et al*., 2018). In addition, the late season drought also frequently occurs causing a large damage to rice grain yield (Jongdee *et al*., 2006). Thus, the evaluation method used in this study comprised of diverse growing environments for genotypes testing. Results revealed that locations selected for present study were inherently different for planting times and toposequences.

Based on grain yield, the locations were distributed in to six groups and mean group grain yield trended to associate with frequency of rainfall except environment group four with lowest rainfall and optimum grain yield. In general, the differences in grain yield were associated with standing water which depends on toposequences in paddy fields. In general, at the same location, the standing water disappeared in the upper to lower positions of a sloping land (toposequence), especially in rainfed lowland rice ecosystem of the Mekong region (Tsubo *et al*., 2006). This could be the reason that contributed to grain yield of the environment group four which located under bottom toposequences. Within each environment group, the plots were consisted of two or three different toposequences. For example, growing environment group one with lowest grain yield, consisted of locations i.e., Samrong (top and middle positions), Borabue (top position), Chomphra (top position), and Nonsang (bottom position). However, variations in grain yield within each group were small even under different toposequences.

In different locations, there would be variation due to frequency of rainfall. However, Inthavong *et al*. (2012) suggested that rice yield losses varied more between toposequences than across different Districts in Laos. Furthermore, the different toposequences led to differentiation in soil nutrients (exchangeable K, organic C and clay content) and water availability in rice fields (Boling *et al*., 2008). The different positions of fields were utilized for screening of unfavourable condition such as drought resistance, while low toposequences were used to evaluate the grain yield potential. The use of different toposequences with multi-location testing was a great opportunity to test the rice genotypes, and utilized a farmer participatory cultivar selection in their fields (Mitchell *et al*., 2014). This indicated that not only location but also toposequence with soil types also affected the grain yield and had high value for rice screening and evaluating. The frequency of rainfall was not different under different toposequence but soil types were different. The lower part of rice field was sandy loam, which had a higher capacity for water accumulation than sand types (Brouwer *et al*., 1985).

Among twelve rice genotypes, the differences in grain yield were highly significant. Significant relationship between days to flowering and genotype grain yield suggested that the genotypes difference in grain yield was due to genotype growth duration. Vergara *et al*. (1966) showed that grain yield of rice genotypes was increased with an increase in growth period up to 140 days. In this study, for genotypes the days to flowering varied from 101 to 129 days, and the short duration rice genotypes were photoperiod insensitive. Similar findings were also reported by comparing 34 rice genotypes under rainfed lowland conditions (Tsubo *et al*., 2009). Rice genotypes with early maturity by taking less days, have been reported to be suitable to water controllable environment such as irrigated condition where exact time of rice planting and harvesting could be managed (Dingkuhn *et al*., 1995; Mahajan *et al*., 2015). Under unpredictable environment such as rainfed lowland, rice genotype with photoperiod sensitivity would be more suitable (Ouk *et al*., 2001). Because, the rice genotype with photoperiod sensitivity was flexible to delay in transplanting and avoid drought at the end of growing season (Yoshida, 1981).

The photoperiod sensitive rice genotypes were found more effective under rainfed lowland rice due to escaping from drought before water loss, especially photoperiod sensitivities were of medium duration (Tsubo *et al*., 2009). It had been reported that rice grain yield might be reduced under delayed planting times due to reduction of filled grains per panicle, lower numbers of panicles, and least 1000-grain weight (Mishri and Kailash, 2005; Akbar *et al*., 2010). However, present results showed that there was a difference between photoperiod sensitivity genotype groups. Group three which consisted of RD-6 and their progenies adapted well in all growing environment and obtained higher grain yield than group one (KDML-105 and RD-15, and SPT-1). Both groups have similar response but RD-6 group has higher grain yield potential. Thus, both groups one and three can be recommended for rainfed lowland conditions in Northeast Thailand.

## CONCLUSION

Rice genotypes with photoperiod sensitivity were found more suitable than insensitivite genotypes for rainfed lowland rice conditions in Northeast Thailand. The use of different paddy positions is helpful in evaluation of the genotypes for adaptation to different soil fertility levels and drought stress conditions. However, different planting times are useful for evaluating the adaptation of genotypes under late planting and late season drought.

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