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The Basic Vegetative Phase and Photoperiod Sensitivity Index as the Major Criteria for Indigenous Upland Rice Production in Thailand under Unpredictable Conditions

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Abstract: Indigenous upland rice (*Oryza sativa* L.) is an important staple food for people. The productivity of upland rice is generally lower than lowland rice since crop yield depends on the amount of rainfall. Climate change is a major problem in rice production due to the unpredictable rainfall. The flowering time, maturity days, growth duration, and photoperiod sensitivity in rice are important for determining productivity. Therefore, in this study, indigenous upland rice germplasm was classified according to their flowering-related traits in the basic vegetative phase (BVP), photoperiod sensitivity index (PSI), grain yield (GY), and yield components. The results reveal that the BVP ranges from 12 to 76 days (mainly less than 30 days) while the PSI ranges from −0.14 to 0.89. Classification of the three groups was based on the PSI: 24 insensitivities (G1; PSI = −0.14–0.30), 214 weakly sensitive (G2; PSI = 0.31–0.70), and 63 strongly sensitive (G3; PSI = 0.71–0.89). Grain yield showed different correlations with day to flowering (DTF), PSI, and BVP in each group. The results suggest that the selection criteria were not only based on GY and DTF but also PSI and BVP. The new ideotypes for upland rice selection under unpredictable conditions such as rainfall and light duration are weakly sensitive (PSI range 0.30–0.60), low BVP (20–30 days), and less than 105 days of DTF, such as ULR189, ULR039, ULR036, ULR403, ULR364, ULR342, and ULR245 genotypes.

Keywords: genetic diversity; flowering time; crop duration; diversity; climate change; germplasm

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1. Introduction

Rice (*Oryza sativa* L.) is an important food crop for Thailand's economy. More than half the world's populations, especially in Asia, consume rice as a staple food [1]. Thailand has nearly 10 million hectares of rice-growing area, with crops mostly consisting of popular improved rice cultivars, such as KDML105 and RD6 [2]. However, ethnic groups in some areas, such as the north and northeast, still grow landrace varieties as the main crop. Thai indigenous upland rice varieties are traditional crops cultivated according to specific areas, locations, geography, and preference. They are mostly grown on slopes and hilly areas of the north, northeast, and southern parts of Thailand. Most of the indigenous upland rice in Thailand has photoperiod sensitivity to prevent environmental effects during the growing season, such as drought. Normally, farmers grow upland rice as a stable crop for household consumption [3,4]. The growing area is mainly under rainfed condition with yield loss prevention depending on flowering time.

Indigenous rice was domesticated with genes, geographics, and genetics involved in nature through human selection [5]. Thailand has a genetically diverse source of rice in Asia, especially indigenous rice which is beneficial for breeding since it can be used as a source of valuable genes and characteristics, being particularly tolerant to biotic and abiotic stresses [3,4]. Indigenous rice has diverse day to flowering (DTF) and photoperiod sensitivity but is normally grown during the rainy season (July to November), especially in Thailand's rainfed areas. Days to flowering and photoperiod sensitivity are important criteria for predicting yield under unfavorable conditions, such as last season drought [6]. Photoperiod sensitivity index (PSI) is the stage that is affected by light duration change from vegetative to reproductive. Most upland rice varieties are short-day plants, especially indigenous germplasm. Upland rice production in Thailand is mainly based on the rainfall pattern. The rainy season begins in May, reaching a peak from July to September then sequentially reducing. Furthermore, the duration of daylight in Thailand becomes short (less than 12 h) in October. Therefore, the decrease in rainfall and short light duration in October is the main factor driving farmer's rice selection of photoperiod sensitivity varieties. Therefore, the identification of photoperiod sensitivity and yield potential in indigenous upland rice is valuable for rice production, especially in indigenous upland germplasm. Moreover, flowering time is an important selection criterion for rice breeding in tropical regions [7] and to enable determination of adaption to specific cultivation areas [8] and mitigate the impact of stress conditions, such as drought.

Climate change is found to affect crop production, with rice grown under rainfed conditions predicted to reduce by 50% due to drought and flood [9,10]. Bi-module rain in the north and northeast of Thailand makes it practical for upland rice planting by direct seeding in the first month of the rainy season (May). However, there is a shortage of rainfall in the middle of the rainy season (August); it reaches a peak in September before reducing again, frequently causing drought throughout the planting season [6]. Moreover, although the rainfall in the northeast of Thailand did not decrease in terms of quantity, the rain affected the cultivation in areas subject to drought or flood, requiring adaptation to cultivation practices [11]. Most lowland rice planting areas under rainfed conditions have moved from transplanting to direct seeding due to the change in rain pattern. However, upland rice requires direct seeding, which is a practical planting option. Therefore, breeders need to find strategies to identify or develop new plant types suitable for the changing environmental conditions.

One adaptation strategy involves accurately matching the different crop durations and moisture availability using photoperiod response to escape or avoid predictable occurrences of stress at critical periods in the crop life cycle [12], such as a strong, weak, or insensitive photoperiod. Consequently, flowering time is an interesting trait used as a selection criterion in breeding to offset the effects of changes in climate or rainfall patterns, especially in upland areas. The basic vegetative phase (BVP) was a determinant of yield in rice, especially for the long BVP variety, which has a higher grain yield than short BVP in insensitive genotypes. However, under terminal drought conditions and late planting, the long BVP was not practical due to the rice cycle requiring at least 30 days for the reproductive period and 30 days for ripening [13]. The long duration of the BVP, therefore, results in yield loss through terminal drought. The flowering time not only depends on photoperiod sensitivity but also the vegetative phase. The BVP was the juvenile growth stage which was not affected by photoperiod and the plant completed BVP before its response to the photoperiodic stimulus for panicle initiation [14]. The BVP determines the rice maturity days, especially for the insensitive variety. The rice harvesting time consists of the BVP (days), 35 days from panicle initiation to flowering, and 35 days from flowering to physiological maturity [14–16]. Consequently, the accumulation of the BVP in the photoperiod group does not change to the reproductive phase until it reaches the critical day length. On the other hand, immediate flowering after completing the BVP is a problem for the short BVP variety due to the low assimilation accumulated in the vegetative period causing a low biomass and grain yield. The BVP and sensitivity type are important for yield prediction, especially in uplands. Therefore, direct seeding in upland fields requires knowledge of the BVP and PSI as important criteria due to the unpredictable planting time and dependence on rainfall.

The PSI and BVP in indigenous rice germplasm are useful for breeding programs and rice selection. The PSI and BVP databases are used in this study for identifying the ideo-plant type design in each environmental condition and growing area, such as upland with short rainfall duration, and suitable vegetative or flowering time is a major yield predictor. Moreover, the correlation of yield, PSI, and BVP remains unclear in indigenous upland rice. The BVP is vegetative period and PSI defines the sensitivity of genotypes, enabling the farmer to plan the appropriate planting time to achieve the best potential yield. Furthermore, the BVP and PSI are used as the selection criteria for rice breeding programs in unfavorable conditions. This information is expected to be highly beneficial in terms of germplasm since the planting time could be set to avoid unfavorable conditions. Thus, this study aims to classify the PSI, evaluate the BVP, yield, and yield components in Thai indigenous upland rice germplasm and their relationships for utilization as a genetic database, and further rice breeding programs in unpredictable conditions.

2. Materials and Methods

2.1. Genetic Materials

This study used 301 accessions of upland rice germplasm (Table S1). The upland rice germplasm was collected from rice growing areas in Thailand (northeastern, northern, central, and southern) by the Rice Germplasm Collection Project of Khon Kaen University, Thailand. In addition, all genotypes in Phapumma et al. [3] was a subset of this study.

2.2. Greenhouse and Field Experiments

Evaluation of the BVP was conducted under greenhouse conditions during the 2020 dry season. A total of 301 accessions were grown in plastic pots, each containing 5 kg of soil and one plant seed. The experiment was laid out in CRD with two replications. The rice seedlings were moved 14 days after planting to dark chambers using trolleys to control the daylight (less than 10 h per day) using the rapid generation advanced (RGA) technique [17] until booting was observed in the mainstem.

The field experiment was conducted on two planting dates during the 2019 wet season in the upland field of the agronomy field crop station, Khon Kaen University, to classify the PSI. The materials were laid out in a partially balanced lattice design with two replications. The first planting took place on 18 June and the second on 7 August 2019 with a 49-day interval to classify the photoperiod group. The direct seeding method and sprinkler irrigation were employed on both planting dates. Fourteen days after seeding, the plants were thinned to maintain three plants per hill. The plot size was 1 × 1 m with rows and plant spacing of 50 and 25 cm, respectively. Fertilizer was applied at a rate of 23.44 kg/ha N, 23.44 kg/ha P_2O_5, and 23.44 kg/ha K_2O at 30 and 60 days after planting. Pesticides and insecticides were used as necessary.

2.3. Data Collection

Days to 50% flowering (DTF) were recorded, representing the number of days from sowing to the time when inflorescences anthesis occurs for more than half the plots of each genotype. The BVP was measured by subtracting 35 days from the days to 50% flowering (DTF) [14]. The PSI was defined following the method used by Immark et al. [18]:

$$\text{PSI} = \frac{(\text{DTF1} - \text{DTF2})}{\text{IBD}} \tag{1}$$

where DTF1 represents the days to 50% flowering of the first planting date and DTF2 represents days to 50% flowering of the second planting date, and IBD refers to the intervals between the first and second planting dates. The PSI was classified into three groups: PSI = 0.00–0.30 (insensitive to the photoperiod (G1)), PSI = 0.31–0.70 (weakly sensitive to the photoperiod (G2)), and PSI = 0.71–1.00 (strongly sensitive to the photoperiod (G3)) [18].

In the PSI experiment, the tiller and panicle numbers were recorded from four marked plants. The plants were harvested at ground level in an area of 0.625 m^2 (four plants in each plot) to determine the grain yield (GY), calculated to 1 m^2. The harvest index was calculated according to the economic yield divided by the biological yield in each plot.

2.4. Statistical Analysis

The cluster was based on DTF, PSI, BVP, panicle number, tiller number, and grain yield using Ward's method with the average arithmetic algorithm, cophenetic correlation, and phylogenetic tree visualization, performed in MEGA7 [19]. The correlation coefficient calculation followed by Gomez and Gomez [20] was used to determine the contributing factors by applying the Pearson correlation coefficient.

3. Results

3.1. Genotype Classification Based on PSI, BVP, Geography, and Yield

The BVP values for Thai indigenous upland rice germplasm ranged from 12 to 76 days (Figure 1). According to the results, more than 200 accessions showed BVP values lower than 20–30 days. This indicates that most Thai indigenous upland rice germplasm has a short BVP, suggesting that the short vegetative period affected the flexibility of the planting time, depending on the rainfall or water conditions. Moreover, the long variety, either by natural or human selection, had a short BVP which was more suitable for this area. The genotypes were classified into three PSI groups based on the method used by Immark et al. [18]. The PSI varied from −0.14 to 0.89 (Figure 2) and 24 accessions showed photoperiod insensitivity with PSI values lower than 0.31 (G1). Weak photoperiod sensitivity was exhibited by 214 accessions, with PSI values from 0.31 to 0.70 (G2), while 63 accessions showed strong photoperiod sensitivity with PSI values greater than 0.71 (G3) (Figure 2). The results indicate that Thai indigenous upland rice germplasm has high genetic PSI diversity, and most of the genotypes exhibited photoperiod sensitivity.

The data shows that the north and northeast mainly grow indigenous upland rice (178 and 79 accessions, respectively) while some upland rice genotypes were grown in the southern (16 accessions) and central parts of Thailand (28 accessions). Furthermore, the distribution of genotypes was based on photoperiod sensitivity and was geographically dependent. Groups 1–3 (G1, G2, and G3) were distributed over four regions from north to south (Figure 2). The results indicate that Thai indigenous upland rice has high genetic diversity for photoperiod sensitivity. However, the distribution of sensitive groups (G2 and G3) was predominant in the north, central, and northeast areas, while the insensitive group (G1) was mostly grown in the southern part of Thailand. In addition, the weakly sensitive genotype group (G2) has been adapted throughout the cultivation areas of Thailand, representing more than half of the planting genotypes.

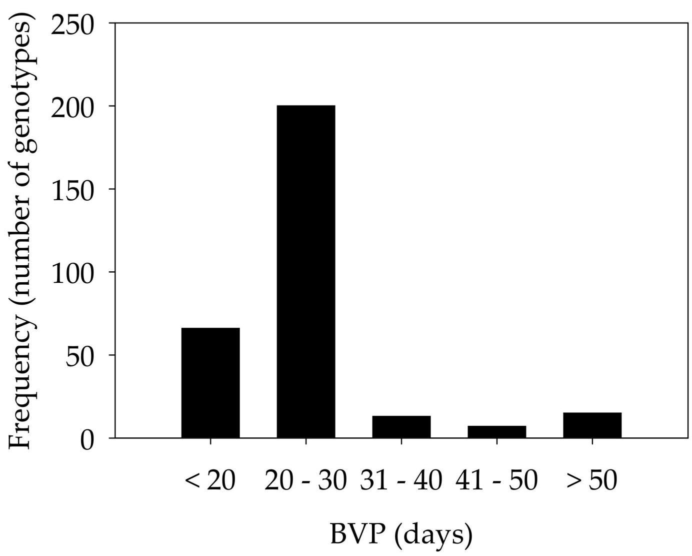

Figure 1. Frequency distribution of basic vegetative phase (BVP) for 301 Thai indigenous upland rice genotypes.

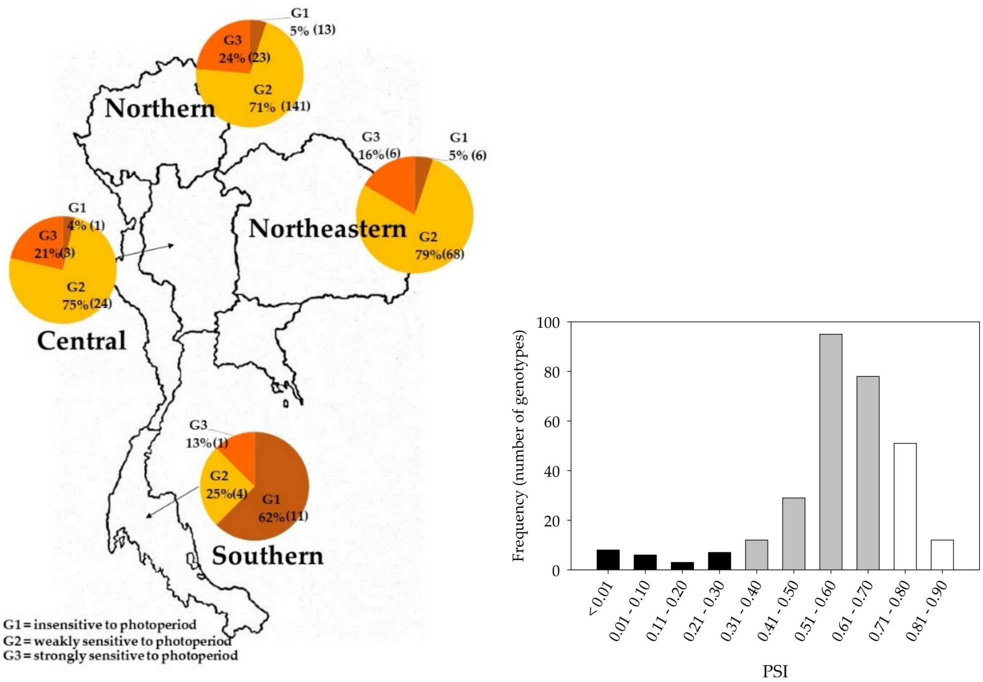

Figure 2. Distribution of indigenous upland rice germplasm in each part of Thailand (**left**), and frequency distribution of photoperiod sensitivity index (PSI) for 301 Thai indigenous upland rice genotypes. The black bar, gray bar, and white bar rice genotypes were insensitive to photoperiod (G1), weakly sensitive to photoperiod (G2), and strongly sensitive to photoperiod (G3), respectively (**right**).

The indigenous upland rice genotypes were classified into five groups based on days to flowering, panicle number, tiller number, and grain yield. The genotype groupings, mainly based on grain yield, consisted of cluster group I with one genotype (ULR076), which had the highest grain yield (656.5 g/m^2). Cluster group III had a high grain yield of 391.2 g/m^2 (362–450 g/m^2) with 11 genotypes, followed by cluster group II, 271.0 g/m^2 (220–250 g/m^2). The yield varied in cluster groups IV (0–136 g/m^2) and V (0–127 g/m^2) with 49 and 163 genotypes, respectively (Figure 3 and Table 1). Some cluster groups contained all photoperiod genotypes: insensitive, weakly sensitive, and strongly sensitive (Figure 3). The highest yielding cluster was in group III, consisting of weakly sensitive (ULR036, ULR039, ULR189, ULR232, ULR245, ULR342, ULR364, ULR377, ULR403, ULR408) and insensitive genotypes (ULR010). On the other hand, cluster group II had high yielding genotypes, such as ULR155 had 350.2 g/m^2 with weakly sensitive, ULR085 had a grain yield of 287.0 g/m^2, and strongly sensitive, while ULR162 had a grain yield of 301.7 g/m^2 and exhibited insensitivity. This indicates that the high yielding genotypes were not only dependent on photoperiod sensitivity.

Table 1. The number of genotypes, PSI, BVP, and grain yield (GY) of each group based on cluster analysis.

Cluster Group	Number of Genotypes	PSI	BVP	GY
I	1	0.33	41	656.5
II	77	0.56 (0.20–0.77) [a]	24.4 (17–42)	271.0 (220–250)
III	11	0.52 (0.29–0.64)	26.0 (18–43)	391.2 (362–450)
IV	49	0.59 (−0.04–0.89)	27.5 (14–73)	30.5 (0–136)
V	163	0.58 (−0.14–0.88)	26.0 (12–76)	143.0 (0–127)

[a] The numbers in brackets represent the lowest and highest values of each trait in the group.

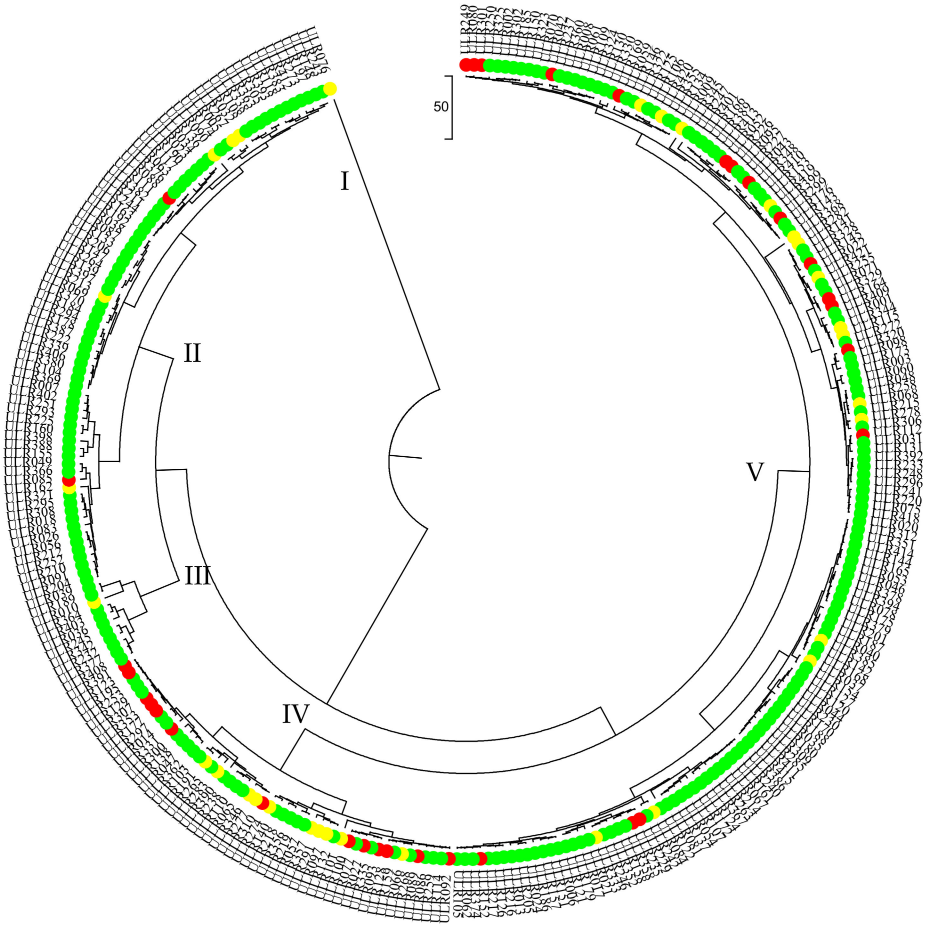

Figure 3. Cluster analysis of 301 indigenous rice germplasm based on days to flowering (DTF), panicle number, tiller number, and grain yield according to Ward's method. The yellow circle represents the insensitive group (G1), the green circle the weakly sensitive group (G2), and the red circle the strongly sensitive group (G3).

3.2. Effect of DTF, BVP, and PSI on Grain Yield

The genotypes were grouped by PSI to reveal the relationship between GY and DTF in each group. Significant differences in correlations were revealed between DTF and GY in each group of genotypes based on the PSI. Moreover, DTF was negatively correlated with GY in all groups, with group 3 (G3) having the highest correlation of all groups ($r = -0.678$ **) (Figure 4). The overall group results indicate that early maturity genotypes have higher grain yield than late maturity genotypes in upland rice. The results reveal that most upland rice genotypes have a higher grain yield than average grain yield, even though rice germplasm is basically low yielding. Interestingly, the results show that rice genotypes with around 90–105 DTF after seeding have high yield potential, especially in the weakly sensitive group (G2). The critical day length of weakly sensitive genotypes was longer in terms of light hours than the strongly sensitive genotypes, for example, weakly sensitive needed less than 12 h/day but strongly sensitive needed less than 11 h/day. In Thailand, daylenght becomes short in September, indicating that on the same planting date, the maturity time was earlier in the weakly sensitive group.

The PSI were calculated between the flowering time of two planting dates that were different from DTF in each genotype. Some genotypes had low PSI (photoperiod insensitivity) but late flowering time (Figure 5). The PSI classification groups were found to be significantly related to GY, with each exhibiting high variation. Group 1 (G1) showed a positive correlation ($r = 0.640$ **) while groups 2 (G2) and 3 (G3) were negatively correlated (r = −0.224 ** and r = −0.243, respectively) with GY (Figure 5A). The photoperiod-sensitive groups (G2 and G3) were found to have increasing PSI values with low yields in upland rice genotypes. According to the results of this study, the selection criteria for upland rice production under rainfed conditions should consist of early flowering and insensitive, and weakly sensitive genotypes. In addition, the BVP was not correlated with GY in weak and strong sensitivity groups, but insensitive groups showed a negative correlation (r = −0.414 *) (Figure 5B). The results suggest that a long growth period under upland conditions produces lower grain yield than early maturity or short BVP, especially in the insensitive group. Moreover, the analysis showed a negative correlation between the BVP with PSI and significant differences in groups 1 and 2 (G1 and G2) but not group 3 (G3) (Figure 5C). The BVP represents the vegetative duration of rice before the reproductive phase, indicating that the strongly sensitive group (G3) had a shorter vegetative phase than the weakly sensitive (G2) and insensitive groups (G1). In contrast, the rice genotypes in group 1 (G1) exhibited a high variation in BVP since the light duration did not affect the flowering or panicle initiation time, suggesting that GY depends on PSI and BVP in all genotype groups.

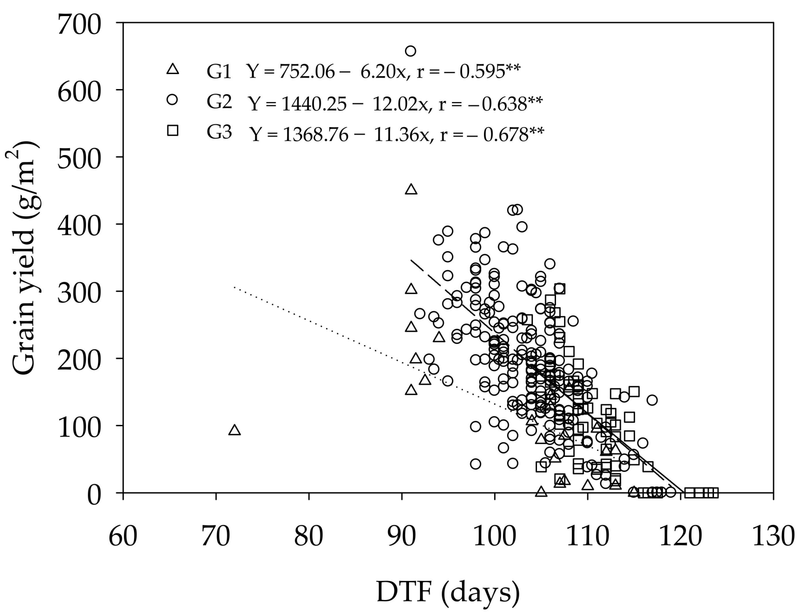

Figure 4. Relationship between DTF and GY in each group. G1 represents insensitive to the photoperiod, G2 weakly sensitive, G3 strongly sensitive, ** represents significance levels at $p < 0.01$.

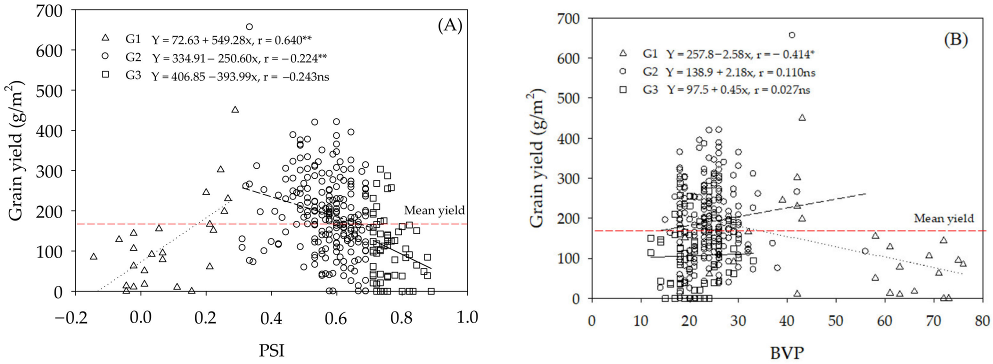

Figure 5. *Cont.*

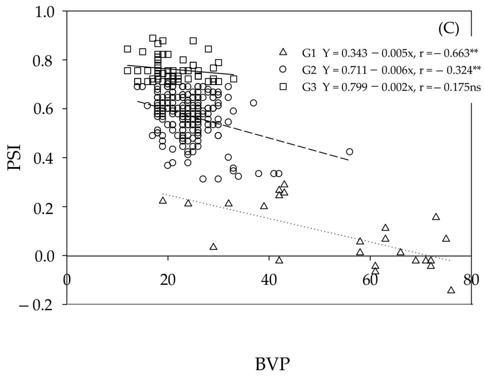

Figure 5. Relationship between PSI and GY (**A**), BVP and GY (**B**), PSI and BVP (**C**) in each group. Triangle = G1 (insensitive), circle = G2 (weakly sensitive), square = G3 (strongly sensitive), while ns, *, and ** represent not significant and significant at $p < 0.05$ and $p < 0.01$, respectively.

4. Discussion

4.1. Genotype Classification Based on BVP, PSI, Geography, and Yield

Rice is known to be a short-day plant [16], with its flowering time dependent on the photoperiod. However, some genotype groups were insensitive to the photoperiod with the flowering time being dependent on thermo-sensitivity [21]. The flowering time and photoperiod sensitivity in rice exhibited significant differences, not only in variety but also temperature, geography, and light intensity, especially the photoperiod-sensitive group [22,23]. In this study, 301 accessions of Thai indigenous upland rice germplasm were classified into three groups based on the photoperiod sensitivity index (PSI) and five cluster groups based on days to flowering (DTF), yield, and agronomic traits (Figures 2 and 3). This indicates that Thai indigenous upland rice germplasm exhibits high genetic variations in PSI, flowering time, and yield performance. In this study, most of the rice genotypes were classified into short BVP (less than 30 days) (Figure 1). The BVP duration affects the days to maturity for rice, especially in the photoperiod sensitive group. Upland rice germplasm was mainly collected by ethnic groups, leading to the selection being based on the natural growing season in each area. The north and northeastern parts of Thailand are the main areas for rice growing under rainfed conditions from June to October. Since the fluctuation and unpredictability of rainfall affects the length of the growing period, a short BVP was selected due to the natural rainfall phenomenon. Moreover, the long maturity period or long BVP was subject to a high risk of late season drought. Most long BVP in genotype group 1 (Figure 2) was grown in the southern part of Thailand due to the long rainy season and different planting times from August to December or harvesting from January to February in flooding years. The variation in BVP supports the criteria for maturity selection, especially in insensitive and weakly sensitive groups of less than 30 days. Therefore, the most suitable BVP was the one considering criteria for predicting the harvesting day that were BVP + 35 days (PI to flowering) + 35 days (flowering to physiological maturity) [14].

In this study, the PSI ranged from −0.14 to 0.89. In general, the PSI tends to range from 0.00 to 1.00. Low temperatures lead to delayed flowering [14], especially in insensitive plants, due to the slow accumulation of thermal degree days [24], slow response during the vegetative phase, and delayed heading date in cool summers [21]. The low temperature on the second planting date resulted in late flowering and minus PSI for insensitive rice genotypes (Figure 2). Moreover, most upland rice genotypes were found to experience photoperiod sensitivity which is important for rainfed cultivation since the unpredictability of rain affects planting time, growth duration, and yield. The start of the upland rice-growing season depended on rainfall, which affects the maturity time. The same maturity time of sensitive genotypes mostly reduced the yield due to the effect of late planting time and late season drought. Late planting time was affected by short dry matter accumulation that resulted in low grain yield. Moreover, weakly sensitive genotypes with long BVP could be subject to late season drought. However, the same maturity time resulted in reduced yield loss by natural enemies, such as birds or rats targeting the plants due to early or late maturity. The same maturity genotypes were also the critical criteria for genotype selection in each planting area. However, the insensitive group (G1) was mostly grown in the southern part of Thailand, which receives more rainfall than the north and northeastern areas.

Furthermore, five group clusters were classified based on grain yield, days to flowering, tiller, and panicle number (Figure 3, Table 1. The high yielding group had mostly weak photoperiod sensitivity, making them suitable for upland rice production in Thailand. The unpredictability of rainfall affected the planting time, especially in strongly sensitive genotypes with low BVP (<20) due to the short biomass accumulation, reducing yield [25] and yield components [26]. Although the strongly sensitive genotypes with a long BVP were a better choice, they were subject to high risk under late season drought. Consequently, the target environment was a major deciding factor in the selection of upland rice. The growing areas in Thailand were sloping or hilly under rainfed conditions, creating a water deficit and runoff according to the percentage of the slope gradient [27]. High yielding genotypes with a BVP of 20–30 days and weak sensitivity (PSI group 2) were suitable for rice production in these areas, such as those in cluster group III: ULR036, ULR039, ULR189, ULR232, ULR245, ULR342, ULR364, ULR377, ULR403, and ULR408.

4.2. Effect of DTF, BVP, and PSI on Grain Yield

The relationship between GY and DTF in each group of indigenous upland rice genotypes showed that late flowering genotypes exhibited lower yield than early flowering genotypes. Rice genotypes with 90–105 DTF mostly exhibited high yield (over mean yield), especially in the weakly sensitive group (G2) (Figure 4). The critical day length of weakly sensitive genotypes was longer than strongly sensitive genotypes, so on the same planting date, the maturity time was earlier in the weakly sensitive. Although the long vegetative period increased the GY by assimilated accumulation [14,28], the late maturity genotypes were at risk of water deficit, especially under rainfed conditions. Although this study used an irrigation system, the percentages of 20–30% did not benefit the plants due to evaporation, high evapotranspiration [29], and high penetration in sandy soil [30]. Therefore, late maturity genotypes were not suitable for rainfed upland conditions, especially in late season drought areas.

The correlation between PSI and GY was negative in the weakly sensitive group (G2) and strongly sensitive group (G3), while positive in G1 (Figure 5A). The BVP in GY was unaffected except for G1 (Figure 5B), while the BVP was correlated with the PSI in G2 and G3 but not in G1 (Figure 5C). Based on photoperiod sensitivity, insensitive and weakly sensitive groups were suitable for upland rice production under rainfed conditions. However, the weakness in the insensitive group produced long BVP genotypes, resulting in low GY (Figure 5B). Moreover, the highest GY was mainly from the weakly sensitive group, making it suitable for upland rice production areas in Thailand due to unpredictable rainfall affecting the growth duration. A delay in the planting date affected the strongly sensitive genotypes, while an early planting date had a greater effect on the insensitive group. For example, a late start to the rainy season affected the late planting date, reducing the growth period of the strongly sensitive genotype, especially those with low BVP (<20). Rice reaching the reproductive stage with low source accumulation affected the GY. However, the strongly sensitive genotypes with a long BVP were another choice for this situation. On the other hand, the early planting date of insensitive genotypes that had early harvesting times affected the grain quality through the high moisture content, or in the strongly sensitive group, long vegetative period was affecting the input factor such as fertilizer, water, and labor. Therefore, the target environment was a major decision factor in selection. Germplasm diversity is beneficial since it has the potential for breeding progress or selection to release the genotypes. The GY, PSI, and BVP were the selection criteria in unpredictable rainfall conditions. Consequently, the most suitable BVP and PSI in each cluster group were considered.

The long BVP and insensitive genotypes were useful in favorable areas with no drought or a long growing duration, such as southern Thailand [11]. The BVP represents the vegetative duration of rice before the reproductive phase. Therefore, a short BVP affects biomass accumulation and GY. Photoperiod sensitivity was the main factor in rice production, especially under late season drought [6,31]. The weakly sensitive group with a suitable BVP (20–30 days) was selected for upland conditions. Moreover, the GY depended on both PSI and BVP (Figure 5). The BVP was related to high PSI (photoperiod sensitivity) in most upland rice germplasm. Consequently, a short BVP did not affect the growth duration due to early or late planting; the rice did not reach the reproductive phase until the critical day length, so the photoperiod sensitivity genotypes mostly had a short BVP in this Thai indigenous germplasm. Furthermore, the main upland rice cultural practice took place in the rainy season, and the maturity time tended to be the same before the dry season. The main upland rice-growing area in north and northeastern regions was mostly subject to late season drought [6], and selection is not only based on GY and DTF but also PSI and BVP. The selection criteria for upland rice genotypes were weakly sensitive (G2) with PSI values ranging from 0.30 to 0.60, low BVP from 20 to 30 days, and DTF of less than 105 days. The flowering times of the selected group ranged from the middle to the end of September, resulting in a high grain yield due to the upland environment being suitable for rice cultivation in Thailand [32]. The main upland rice-growing area in the north and northeastern regions, mostly subject to late season drought, were selected not only on the basis of GY and DTF but also PSI and BVP. The ideotype for upland rice genotype criteria consists of weakly sensitive (G2) with PSI values ranging from 0.30 to 0.60, low BVP of 20–30 days, and DTF of less than 105 days. For example, ULR189 (PSI 0.60, BVP 26 days, DTF 102 days, GY 421 g/m^2), ULR039 (PSI 0.53, BVP 24 days, DTF 102 days, GY 420 g/m^2), and ULR403 (PSI 0.47, BVP 26 days, DTF 95 days, GY 388 g/m^2). This ideotype will provide good adaptation throughout the target area with weak sensitivity, a short vegetative phase, and short time to maturity to mitigate the impact of unpredictable rainfall conditions and escape drought.

5. Conclusions

Thai indigenous upland rice showed variation in their response to photoperiod sensitivity. The rice was separated into three groups, most of which were weakly sensitive (G2) with a short BVP (less than 30 days). The ideotype for upland rice selection exhibited weak photoperiod sensitivity (G2) with a low BVP (20–30 days), DTF of less than 105 days, and PSI values from 0.30 to 0.60 (weakly sensitive), such as ULR189, ULR039, ULR036, ULR403, ULR364, ULR342, and ULR245 genotypes. These genotypes should be selected as breeding material or for promoting upland rice production in the planting area.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12040957/s1, Table S1: The list of 301 accessions and their locations, DTF, PSI, BVP, panicle number, tiller number, and grain yield.

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