

Screening for Drought-Tolerant and Low-Input Responsive Upland Rice Landraces

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Abstract

Productivity potentials of upland rice landraces (URLs) are continuously compromised by scanty water supply due to competing priorities for irrigations and fluctuations in agro-ecological conditions peculiar to low-input farming systems. A growing demand for rice amidst decline in productive agricultural areas plunges into an urgent contribution of marginal areas critical in attaining food sufficiency among Filipino households. Agronomic performances of URLs locally found in Catanduanes province, Philippines were evaluated in a replicated trial utilizing three URLs: Kamanang [1], Kadari [2] and Bulaw [3]. The experimental set-up was closely monitored for consistent dry moisture content and zero fertilizer application. Results were significant for traditional upland landraces: *Kamanang* and *Kadari*, scored in terms of higher germination rate, increment plant height and the number of tillers during the vegetative stage. Leaf color gradations, although statistically not significant across cultivars, were suggestive of varying adaptive performance between traditional cultivars subjected to low-input system. Putative low-input responsive lines indicated by the higher survival percentage and overall agronomic responses were selected from the study site. Screened lines took part of the advance population which would be potentially able to tolerate poor soil conditions (*i.e.* poor storehouse of water and nutrients) especially in areas with edaphological constraints and changing rainfall distribution pattern. The development of putative drought tolerant lines among URLs forms the most economical solution implicated to areas with limited access to agricultural interventions.

Keywords

Upland Rice Landraces, Low-Input System, Edaphological Constraints

1. Introduction

Rice (*Oryza sativa*) is the staple food for 90% or more Filipinos and provides about 62.5% household income for 11.5 million families [1]. It contributes 16% and 3.5% to the Gross Value Added (GVA) and the Gross Domestic Product (GDP), respectively [2]. It is not surprising that 33% of the country's agricultural lands are devoted to rice [3]. Specifically in Catanduanes, 4367 ha are devoted for upland rice farming and have produced 13717.34 MT of rice in 2012 [4].

Based on International Rice Research Institute (IRRI) report in 2009, upland rice cultivars in the Philippines range from 120 to 180 cm attainable height at maturity. Each plant usually has 2 to 4 productive tillers bearing large panicles with many grains per panicle ranging from 150 to 300. The duration of the vegetative phases of upland rice differs with varieties. The reproductive and ripening phases are fairly constant for most varieties. The reproductive phase lasts about 35 days; the ripening phase lasts about 30 days. The time from sowing to harvest ranges from 80 to 180 days or longer [5].

The Philippines are in "high-risk" in terms of food security basing criteria on food affordability, availability and safety. This directly implies the public health problem of the country on nutrition. Survey says 1 out of 4 Filipino children below 5 years old are underweight and stunted [6]. Whilst in a 2010 survey report among the 25 provinces in the country with long standing or chronic malnutrition, Catanduanes province had recorded 23.64% malnutrition rate affecting a very high percentage of pre-school children [7]. Upland rice farming is considered as an important initiative in attaining the goal of rice sufficiency in the region and in the country as well. Farming on an environment with 18 degrees slopes, requires less soil fertilizer application, prone to erosion and water unavailability; however it provides an opportunity to solve the household food scarcity, income and nutrition. Upland rice is widely cultivated in West Africa, Latin America and Southeast Asia especially Indonesia, Thailand, and Laos. It is well-adapted to poor environments with low-to-medium grain yields. The major problem of Upland Rice farming, however, may lodge under good management. Besides other factors, drought is the most limiting factor causing reduction in rice yield when average rainfall does not meet the water requirement by the crop [6] [8]-[10].

Upland rice farming is being threatened by climate change, ensuing an erratic intensity pattern and average rainfall. Moreover, some areas are experiencing longer dry periods whilst other regions are confronted with heavier rains [11]-[14]. The so-called El-Niño phenomenon causes significant reduction in yields of major crops including rice in Asian countries (*i.e.* Malaysia, Indonesia, Thailand, Philippines) in 1992 and 1997 [15]. The Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) claimed possible development of El-Niño phenomenon that may begin on the last quarter of 2014 and will last up to the first quarter of 2015 [16]. This rainfall pattern is foreseen to continue, which may give crucial effects to rice farming or agricultural sector as a whole since they are largely dependent on climatic conditions in putting food secured. To reduce or endure the effect of the changing climate, development of drought resistant upland rice lines with drought tolerant is the most economical solution. Lines with drought tolerance can be identified through selection from high yielding donor lines using Drought Responsive Index (DRI) under drought stress conditions. Drought tolerance variability in upland rice lines is a well-known fact [6] [8] [9]. Moreover, high genotypic variability of rain fed and irrigated rice cultivars possessing different plant traits were also reported [17]-[21].

Locally Adapted Cultivars (LACs) or traditional Upland Rice Landraces (URLs) commonly found in resident upland rice farmers in Catanduanes were the mainstream of cultivations in the absence of improved lines or cultivars responsive to both nutrient-deficient soils and low water availability or irrigation system. Seed exchanges among neighboring farms formed part of the farmer's habit in search for new seeds to be planted for subsequent cropping season. Hence, a study was focused on screening low-input rice responsive lines among three rice cultivars which the resident farmers of Catanduanes were using to identify potential upland rice lines which would thrive well on low-input system especially during dry periods. The agronomic traits of three upland rice varieties were scored in terms of 1) date to seedling emergence, 2) plant height, 3) number of true leaves, 4) leaf color, 5) number of tillers, 6) percent survival among landraces in response to low-input system, and 7) number of potential lines across cultivars.

2. Materials and Methods

2.1. Collection of Indigenous Upland Rice Landraces

The study used three upland rice landraces (*i.e.* *Kamanang*, *Kadari* and *Bulaw*) collected within the province of

Catanduanes, Philippines (**Table 1**). Pertinent features like local name and maturity of each cultivar were indicated based on the first hand information given by the farmers from whom the seeds were collected. Landraces derived from on-field collections were the mainstream of cultivations the farmers had been using through years in nearly remote barangays of Catanduanes, Philippines.

2.2. Experimental Design, Seedling Establishment and Field Layout

The study was conducted at the College of Agriculture and Fisheries Crop Experiment Station (CAF-CES), Catanduanes State University through pot experiment following a Completely Randomized Design (CRD) for three Upland Rice Landraces subjected to low-input culture with maintained dry moisture content, 7.0 pH level, high density planting and with zero fertilizer application. Qualitative moisture content (*i.e.* dry, moist or wet) was determined using soil moisture tester (4 in 1 Soil Survey Instrument). Calibration and critical monitoring for dry moisture content of the low-input set-up was facilitated through the use of sandy:stony (1:1 v/v) modified growing medium, categorically known to be droughty, hence, a poor storehouse for both water and nutrients (**Figure 1**).

2.3. Data Collection

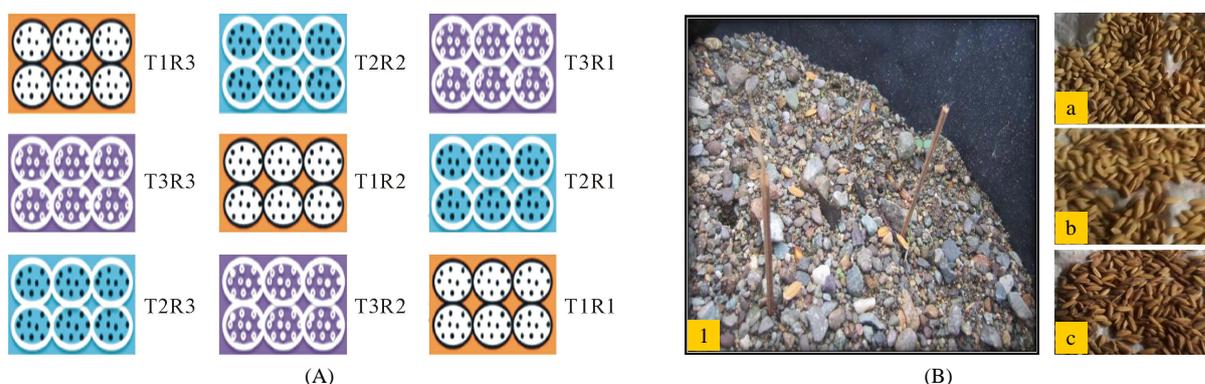
The agronomic traits were periodically measured at the vegetative stage covering specific stages from rice emergence to early tillering stage of each cultivar for about 42 days. Data collected include the following parameters: periodic germination percentage, number of tillers, plant height (cm), number of true leaves, green color gradient/score, percentage survival and number of potential low-input rice responsive lines across landraces.

2.4. Data Analysis

All data were analyzed using one-way analysis of variance (ANOVA) technique, by using SPSS 17.0 software to determine the degree of significance between treatments. Mean separation among significant treatments was

Table 1. Identity of the upland rice landraces collected in the province.

Landrace	Code	Local Name	Maturity
Landrace 1	La1	<i>Kamanang</i>	5 - 6 months
Landrace 2	La2	<i>Kadari</i>	4 months
Landrace 3	La3	<i>Bulaw</i>	5 - 6 months



R1-Replicate 1, R2-Replicate 2, R3-Replicate 3
 Total Number of Polyethylene bag = 54
 Polyethylene bag dimension = $4 \times 4 \times 11$ in³
 Polyethylene bag to seed ratio = 1:10
 Polyethylene bag per replicate ratio = 6

Figure 1. (A) Experimental layout showing different treatments in replicated trials; (B) Low-input planting medium; inset a-c: *Kamanang*, *Kadari*, *Bulaw* URLs, respectively.

done using LSD pairwise comparison (*i.e.* $p \leq 0.05$).

3. Result and Discussion

3.1. Date to Seedling Emergence of Upland Rice Landraces

The analysis of variance (ANOVA) test for percent germination of three upland rice landraces observed from first to eighth Day After Sowing (DAS) had revealed significance among treatments. Mean analysis indicates that in terms of percent germination, “*Kamanang*” and “*Kadari*” landraces have significantly the same germination percentage compared to “*Bulaw*” landrace which shows consistently least percent germination throughout the 8th day observation period. Variations in germination percentage could be the effect of environmental stressors (*i.e.* temperature etc.) [22] (Table 2).

3.2. Plant Height

In terms of plant height, the result showed significant differences between treatments at $p \leq 0.05$. Summary of statistical results through 6th weeks observation period is presented on Table 3. The results revealed that “*Kamanang*” and “*Kadari*” landraces obtained comparative increment in plant height on a weekly basis relative to “*Bulaw*” landrace. The fluctuating mean, however, from the 3rd to the last observation period of “*Kadari*” landrace might be implicated to staggered seedling death while the “*Bulaw*” landrace obtained least survival of seedlings and accumulated the lowest average plant height when subjected to low-input system.

3.3. Average Number of True Leaves

In terms of the number of true leaves, “*Kamanang*” and “*Kadari*” cultivars exhibited similar performance on the initial weeks (*i.e.* 2nd to 3rd weeks) of the observation period than “*Bulaw*” cultivar. However, “*Kamanang*” cultivar had shown consistently highest number of synthesized true-leaves during vegetative stage. The results underscore the significant adaptation of “*Kamanang*” cultivar for leaf formation relative to intermediate adaptation of “*Kadari*” cultivar and the sensitivity of “*Bulaw*” cultivar to drought and nutrient deficiencies (Table 4).

3.4. Leaf Color Score

In terms of the green color gradation, all treatments (*i.e.* upland rice landraces) have statistically the same color gradient score which was measured using a standard leaf color chart [23] from 3rd week to 6th week duration.

Table 2. Germination percentage (%) of three upland rice landraces from 1st to 8th day of the observation period.

Landrace	Germination Percentage*							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
<i>Kamanang</i>	0	0	100 ^A	100 ^A	100 ^A	100 ^A	100 ^A	100 ^A
<i>Kadari</i>	0	0	91.67 ^A	96.11 ^A	100 ^A	100 ^A	100 ^A	100 ^A
<i>Bulaw</i>	0	0	0.56 ^B	3.33 ^B	3.38 ^B	9.44 ^B	13.3 ^B	20 ^B

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

Table 3. Average weekly increment in plant height (cm).

Landrace	Germination Percentage*				
	Week 2	Week 3	Week 4	Week 5	Week 6
<i>Kamanang</i>	12.89 ^A	15.45 ^A	19.17 ^A	18.39 ^A	19.67 ^A
<i>Kadari</i>	11.83 ^A	12.95 ^A	11.33 ^A	10.78 ^A	11 ^A
<i>Bulaw</i>	0.67 ^B	0.67 ^B	0.5 ^B	0.67 ^B	0.83 ^B

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

The green color gradient score of the three rice landraces from 3rd to 6th week's observation is shown on **Figure 2**. Though the mean score across treatments and periods revealed no significant difference, it is numerically noteworthy to consider the differing adaptive behaviour of the three rice landraces grown under restricted medium. The “*Kamanang*” landrace observed quiescent performance in leaf color synthesis for almost a month duration but surprisingly obtained significant scores for the 5th and 6th weeks periods; the “*Kadari*” cultivar had shown consistent average (*i.e.* LCC score = 2) throughout. The seemingly adaptive and responsive strategy indicated by increasing scores of the “*Bulaw*” landrace (LCC values usually higher than 2) may possibly indicate an exhaustive mechanism of this landrace as there had been recorded low percent germination, hence, lesser seedlings mean greater access to resources than do close density planting.

3.5. Tillering Ability of Rice Cultivars

The onset of active tiller formation for these upland rice landrace was observed at the 5th week observation and persisted until 6th week. The tillering ability on the 5th week delineated no significant difference among landraces. The “*Kamanang*” landrace, however, had shown a remarkable increase in number of tillers even subjected under prolonged low-input system (*i.e.* presence of low soil moisture content, poor nutrient and high density planting). On the other hand, treatment 3 “*Bulaw*” landrace showed no response in number of tillers grown in a restricted medium (**Table 5**).

Table 4. Average number of true leaves of three rice cultivars from the 2nd to 6th week of the observation period.

Landrace	Germination Percentage*				
	Week 2	Week 3	Week 4	Week 5	Week 6
<i>Kamanang</i>	1.6 ^A	1.55 ^A	1.92 ^A	1.84 ^A	1.9 ^A
<i>Kadari</i>	1.24 ^A	1.30 ^A	1.13 ^B	1.08 ^B	1.08 ^B
<i>Bulaw</i>	0.07 ^B	0.07 ^B	0.63 ^C	0.07 ^C	0.08 ^C

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

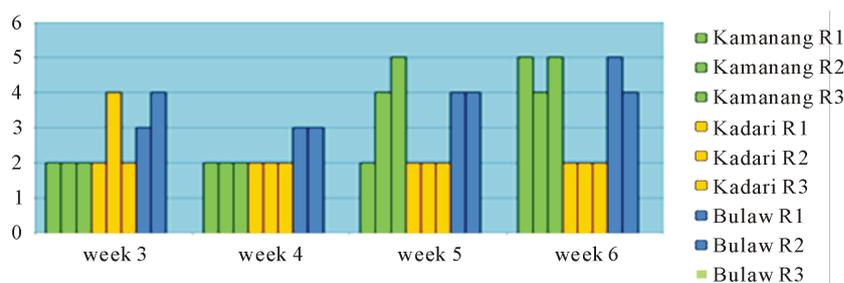


Figure 2. Green color gradient score of the three rice cultivars per replicate from the 2nd to 6th week of the observation period.

Table 5. Number of tillers of three rice landraces from the 3rd to 6th week of the observation period.

Landrace	Germination Percentage*	
	Week 5	Week 6
<i>Kamanang</i>	0.78 ^A	1.61 ^A
<i>Kadari</i>	0.14 ^A	0.7 ^B
<i>Bulaw</i>	0 ^A	0 ^B

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

3.6. Periodic Survival Percentage in a Modified Low-Input System

Two landraces (*i.e.* “*Kamanang*” and “*Kadari*”) were significant than “*Bulaw*” landrace but followed a general decline in survival percentage of seedlings based on the weekly observations. There had been greater count of seedlings observed from the two significant treatments (*i.e.* *Kamanang* and *Kadari* landrace) relative to the low adaptability of “*Bulaw*” seedlings in the study site (Table 6).

3.7. Number of Low-Input Responsive Lines across Cultivars

The three upland rice landraces derived from on-field collections had shown two degree of response to poor soil type. “*Kamanang*” and “*Kadari*” landraces exhibited significant number of potential lines selected than “*Bulaw*” landrace based on the test conducted. Results might be implicated to the population structure of each landrace which existed through years of cultivation under farmer’s field; “*Bulaw*” landrace reflected a nearly homogenous population structure that offers higher sensibility to nutrient and water limitations. Conversely, “*Kamanang*” and “*Kadari*” landraces suggested relatively mixed/heterogenous population structure that offers variability for adaptive trait(s) being considered. The higher number of potential lines selected can be well correlated to the low-input adaptability of the two cultivars observed in the study (Table 7).

3.8. Agronomic Performances of Upland Rice Landraces

Since water stresses affects plant germination, selection of survival among the fittest genotypes has been employed to identify potential drought-tolerant/resistant lines [24]–[28]. *Kamanang* and *Kadari* upland rice landraces (URLs) expressed remarkable germination rate with the onset of complete (100%) germination percentage on the 3rd and 5th Days After Sowing (DAS), respectively. When water is limited, rice cycle was prolonged; plant height was reduced [29]. In the current study, the maximum height reached by *Kamanang*¹ landrace (*i.e.* statistically similar to *Kadari* upland landrace) was approximately 20 cm (by which other author posed that it may reach up to 30 cm on the late vegetative stage [30]), however plant height may differ with respect to genotypes. Also significant differences in terms of number of leaves between the three landraces were recorded. *Kamanang* and *Kadari* landraces have the highest number of leaves. This may be an indication that these lines have adaptive expressions on drought and low nutrient soil condition relative to *Bulaw* landrace’ consistently poor performance under a modified sandy:stony (1:1 v/v) growing medium. Nitrogen which constitutes the green leaf color of the leaves is the most limiting plant nutrient element where it is the main driver of plant growth and

Table 6. Weekly survival percentage of three rice cultivars.

Landrace	Germination Percentage*				
	Week 2	Week 3	Week 4	Week 5	Week 6
<i>Kamanang</i>	59.44 ^A	57.22 ^A	56.66 ^A	46.11 ^A	44.43 ^A
<i>Kadari</i>	58.33 ^A	55 ^A	45.55 ^A	33.89 ^A	32.22 ^A
<i>Bulaw</i>	19.98 ^B	19.98 ^B	19.98 ^B	19.98 ^B	19.98 ^B

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

Table 7. Number of screened lines from three rice landraces responsive to low-input system.

Landrace	Number of Screened Lines*
<i>Kamanang</i>	35 ^A
<i>Kadari</i>	25 ^A
<i>Bulaw</i>	2 ^B

*Mean(s) in a column having similar letter(s) is/are not significant at $p \leq 0.05$ level of significance.

¹Screening for drought-tolerant and low-input responsive upland rice landraces.

yield [31]. However there were no significant differences between the three landraces in terms of leaf color gradient (below = score 2). Cultivars exhibited a low nitrogen assimilation implicated by the low nutrient availability and the ease with which nutrients are present under dry soil moisture content of the medium. Water deficit also reduces rice tillering ability [32]. In the study tillers appeared on the 5th and 6th week observation period [31]. At the end of the six week observation period (*i.e.* seedling to early tillering stage) survival percentage of the three landraces subjected to the dry and low-nutrient soil media was recorded. *Kamanang* and *Kadari* landrace exhibited significant number of survived lines. The study is in accordance with the findings of other authors proving variations in different plant traits (*i.e.* drought tolerant lines) [6] [8] [9] [17]-[21]. Drought-tolerant trait might be recognized as the most important trait to be improved in rice [15]. Screened lines as delineated by its agronomic performances were potential selections with drought tolerance character crucial for optimal yield among upland rice landraces.

4. Conclusion

Putative selections from *Kamanang* and *Kadari* upland rice landraces exhibited agronomic behaviors that responded positively under low-input culture system. Variability for the agronomic traits suggests population structure of traditional landraces fortuitously mixed-up through subsequent cropping cycles. Advanced selections of drought-responsive lines prelude URLs development in specific breeding program relative to agro-climatic fluctuations.

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