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RESEARCH ARTICLE

Gowth and yield performance of upland rice (*Oryza sativa* l.) cultivars under rainfed lowland conditions

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Abstract

Upland rice has diverse agro-ecological attributes that can tolerate changes brought by climate change. Hence, this study aimed to determine the performance of upland rice cultivars under rainfed lowland conditions, assess the root growth of upland rice cultivars under rainfed lowland conditions, and evaluate the profitability of growing upland rice cultivars under rainfed lowland ecosystems. This was laid out in a Randomized Complete Block Design (RCBD) with three replications. Twelve rice cultivars were designated as treatments, however, only seven rice cultivars survived namely; Caimpas, Black rice, Red rice, Speaker, NSIC Rc192, PSB Rc18, and NSIC Rc27 that showed significant differences on agronomic characteristics, root and shoot parameters, yield, yield components, and harvest index. The five drought-tolerant upland rice cultivars such as Perya, Remolites, Kalinayan Monos, Tukoran, and Lebolebo showed permanent wilting due to non-adjustment of said cultivars to changes in growing conditions from sufficient irrigation water during early growth to low soil moisture and absence of precipitation during the reproductive growth phase. Improved upland rice variety NSIC Rc27 performed excellently under limited soil moisture through early heading and maturity, and high grain yield as mainly contributed by its heavier straw yield, an abundant number of productive tillers, higher filled spikelets, the heavier weight of seeds, high harvest index and adjustment of aforesaid cultivar to drought. Thus generated the highest gross margin of 1,823.16.00 USD. Therefore, it is recommended to grow NSIC Rc27 under rainfed lowland ecosystems even if this cultivar is experiencing limitations on soil moisture conditions.

Keywords: Cultivar; Ecosystems; Productivity; Rainfed lowland; Upland rice

Introduction

Rice (*Oryza sativa* L.) is a major food crop for most of the population and serves as a staple food for the people of Asia, Latin America, and Africa (Frageria, 2014). This crop is the main source of income and employment for a huge population of rural landless workers. It is a source of energy of two-thirds of the world's population providing about 20 percent energy and 15 percent protein for the dire human needs (Barberena *et al*, 2011). Increasing agricultural production in the face of a growing population is one of the major challenges of the country. As of 2018, the country's population grew to 106,512,074 people (shttp://www.worldometers.info/world-population/philippines-population/). With an increasing population nowadays, farmers are challenged to produce a higher yield of rice. However, due to climate change and unpredictable weather conditions, intense heat led to the reduction of soil moisture and heavy

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rainfall, caused flooding of crops (Colmer, 2003).

The Department of Agriculture challenges farmers to adopt measures to support the food requirement of the growing population albeit the ill-effects of climate change. Cultural management practices are suitable for a certain location implemented by farmers to increase grain yield (Dickie et al., 2014). Aside from management techniques, new varieties are developed by plant breeders to effect higher yield. This is to help meet the domestic needs of the country by increasing tolerance to inclement conditions. The variety or cultivar, which can adapt to changes in climatic and micro-climatic conditions, is a big boost to rice farmers. However, there are varieties, which are being developed for an area, and sometimes they do not perform well especially in rainfed lowland conditions where availability of water is not certain. Growing upland rice cultivars instead of the rainfed lowland cultivars might minimize the negative effect of low rainfall. Planting upland rice variety in a rainfed lowland ecosystem can be a good strategy that can mitigate climate change.

Determining the variety that can favorably be grown in a rainfed rice ecosystem will help farmers in choosing the right variety to be planted to attain higher grain yield. Upland rice grows well in areas where there is limited moisture. Thus, upland rice may be an alternative in the rainfed lowland ecosystem. It is, therefore, important to identify upland rice cultivar and/or variety that can favorable be grown under rainfed lowland conditions to attain rice self-sufficiency. Hence, this study aimed to determine the growth and yield performance of upland rice cultivars under rainfed lowland conditions; assess the root growth of upland rice cultivars grown under rainfed lowland conditions, and evaluate the profitability of growing upland rice cultivars under the rainfed lowland ecosystems.

Materials and Methods

This study was conducted under rainfed lowland ecosystems at Brgy. Palhi, Baybay City, Leyte, Philippines. The experimental area of 482.8 m^2 was prepared by plowing and harrowing alternately using a hand tractor twice at the biweekly interval. After the last harrowing operation, dikes were constructed to impound the water. Ten soil samples were collected randomly before transplanting. These were submitted for the determination of soil pH (Potentiometric Method at 1:1 soil-water ratio, PCARR, 1980), total N (Kjedahl Method, ISRIC, 1995), organic matter (Walkley-Black Method, Nelson, and Sommers, 1982), available P (Olsen Method, Olsen, et al., 1954), and exchangeable K (ammonium acetate) extraction method using atomic absorption spectrophotometry (ISRIC, 1995) at the Central Analytical Services Laboratory (CASL), PhilRootCrops, Visayas State University, Visca, Baybay City, Leyte, Philippines.

The area was laid out in a Randomized Complete Block Design (RCBD) with three replications and twelve rice cultivars as treatments. However, only seven rice cultivars survived and were analyzed statistically. Each replication was divided into twelve treatment plots with each measuring 10 sq. m. at 5 m by 2 m. Then, alleyways between replications and treatment plots were separated by 1.0 m and 0.4 m respectively, to facilitate farm operations, management, and data gathering. The different treatments were designated as follows: T_1 = Caimpas, T_2 = Black Rice, T_3 = Red Rice, T_4 = Speaker, T_5 = NSIC Rc192 (Rainfed lowland variety, check), T_6 = PSB Rc18 (Irrigated lowland variety, check), T_7 = NSIC Rc27, T_8 = Perya, T_9 = Remolites, T_{10} =

Kalinayan Monos, T_{11} = Tukoran and T_{12} = Lebolebo.

Based on the seeding rate of 40 kg ha^{-1}, seeds for each cultivar were used in this experiment. The seeds of the different upland rice cultivars were soaked, incubated, sown, and raised in the seedbed for fifteen days. Seedlings were transplanted at the rate of one seedling per hill at a distance of 20 cm x 20 cm. Missing hills were replanted five days after transplanting. Complete fertilizer (14-14-14) and urea (46-0-0) was used following the recommended rate of 90-60-60 kg ha^{-1} N, P_2O_5, and K_2O. Complete fertilizer (14-14-14) at the rate of 0.43 kg was applied basally per treatment plot one week after transplanting. The remaining N was top-dressed 45 days after transplanting at the rate of 0.19 kg per treatment plot**.** In controlling weeds, rotary weeding operations were done two weeks after transplanting. Spot weeding operation around each hill was conducted to remove weeds not incorporated during rotary weeding. Insect pests and diseases were controlled from seedbed preparation until harvesting of the crop. Harvesting was done when 85% of the grains were hard or firm, turning yellow color. Sharp sickles were used to cut the rice panicles at the base excluding border plants in each treatment plot. The sample panicles within the harvestable area (5.52 m^2) in each treatment plot underwent threshing, sun-drying, and winnowing before gathering of necessary data.

Data Gathered

The agronomic characteristics were the number of days to heading and maturity, plant height (cm) at maturity, leaf area index (LAI), fresh straw yield (t ha^{-1}), number of nodal roots per plant, nodal root axis length (cm) per plant, root dry weight (g) per plant, shoot dry weight (g) per plant and root: shoot ratio per plant were done. The yield and yield component parameters gathered relative to the number of productive tillers per hill, panicle length (cm), panicle weight per hill (g), number of filled and unfilled grains per panicle, percentage (%) of filled grains, and grain yield (t ha^{-1}) were also undertaken. Harvest index and cost and return analyses were also determined and from which gross income was determined by multiplying the yield of each treatment plot (kg) by the current market price of rice grains at USD 0.40 per kilogram. In determining the gross margin, the total expense from every treatment was subtracted from the gross income.

Total weekly rainfall (mm), average daily temperature (minimum and maximum, °C), and relative humidity (%) obtained from the records of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Station, Visayas State University, Visca, Baybay City, Leyte, Philippines were collected. Statistical analysis of data gathered was done using the Statistical Tool for Agricultural Research (STAR). Honestly, Significant Difference or Tukey's test was used for comparison among treatment means.

Results and Discussion

The meteorological data (Table 1) showed that the total precipitation during the conduct of the experiment reached 434.16 mm or an average of 22.85 mm weekly, which was below the optimum requirements (1,200 mm-1,500 mm) for normal growth then the development of upland rice as mentioned by Tuong and Bouman, 2003. The mean minimum and maximum air temperatures throughout the conduct of the study reached 24.70 ^{0}C and 28.79 ^{0}C, respectively. These were within the optimum requirements (20-35 ^{0}C) of upland rice for normal growth from planting to harvesting (Tuong and Bouman, 2003). Moreover, the mean relative humidity recorded at 82.21 % was sufficient for the growth of upland rice (Lafitte and Bennett, 2002).

Table 1. Total and mean rainfall (mm), minimum and maximum temperatures, and relative humidity throughout the duration of the study obtained from PAG ASA station from December 22 to May 5, 2019

Period	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)
		Minimum	Maximum	
Total	434.16	469.38	546.93	1,562.02
Mean	22.85	24.70	28.79	156.20

Soil Chemical Properties

Results of initial soil analysis revealed that the soil had a pH of 5.46, 3.07% organic, and 0.21% total nitrogen, 116.64 mg kg $^{-1}$ available phosphorus, and 1.14 me 100g^{-1} exchangeable K (Table 2). The results indicated that the soil was strongly acidic with a medium amount of nitrogen, organic matter (OM), and a high amount of both available phosphorus and exchangeable K (Landon, 1991).

Table 2. Chemical properties of the soil before harvesting of upland rice (*Oryza sativa* L.) cultivars grown under rainfed lowland conditions

Treatment	pH (1:1) soil: water	Organic Matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchange-able K (me 100 g^{-1})
Initial soil analysis	5.48	3.07	0.21	116.64	1.14

Agronomic Characteristics

Statistical analysis revealed that all agronomic parameters were significantly affected by the different rice cultivars tested (Table 3). Out of twelve cultivars tested, there were only seven rice cultivars, which survived until maturity due to the limitation of rainfall throughout the conduct of the experiment. Improved upland rice variety NSIC Rc27 significantly headed (71.67 days) and matured earlier with a maturity period of 99.33 days after sowing compared to other upland rice cultivars except for Black rice, Red rice, and NSIC Rc192. Caimpas and Speaker (traditional upland cultivars) remarkably headed and matured late at 99-135 and 99-134 days, respectively. Relative to plant height (cm), Speaker significantly grew taller with 109.78 cm than those of other cultivars except Caimpas with a height of 99.31 cm. Results of the study construed with the observations of Talyaran (2015) that Speaker was taller among traditional upland rice cultivars evaluated.

Table 3. Agronomic characteristics of upland rice (*Oryza sativa* L.) cultivars grown under rainfed lowland conditions

Cultivar	Number of days from sowing to		Plant Height (cm)	LAI	CF	Fresh Straw Yield
	Heading	Maturity				(t ha^{-1})
T_1 = Caimpas	99.00 ^{a}	135.00 ^{a}	99.31 ^{ab}	1.84 ^{b}	0.74	1.22 ^{b}
T_2 = Black rice	80.67 ^{bc}	107.33 ^{bc}	85.06 ^{c}	1.16 ^{b}	0.71	0.94 ^{b}
T_3 = Red Rice	83.00 ^{bc}	110.00 ^{bc}	86.48 ^{c}	1.46 ^{b}	0.72	1.03 ^{b}
T_4 = Speaker	99.00 ^{a}	134.00 ^{a}	109.78 ^{a}	2.73 ^{a}	0.74	0.95 ^{b}
T_5 = NSIC Rc192	76.00 ^{bc}	105.00 ^{bc}	93.62 ^{bc}	1.33 ^{b}	0.72	0.98 ^{b}
T_6 = PSB Rc18	87.00 ^{b}	117.00 ^{b}	83.38 ^{c}	1.21 ^{b}	0.73	1.03 ^{b}
T_7 = NSIC Rc27	71.67 ^{c}	99.33 ^{c}	83.92 ^{c}	1.54 ^{b}	0.70	4.27 ^{a}
Mean	85.19	115.48	91.65	1.61		1.49
C. V. (%)	4.92	4. 04	4.25	17.33		17.31

Means within column followed by the same letter were not significantly different at 5 % level, HSD

In the case of leaf area index (LAI), using the established correction factor (CF), Speaker significantly obtained the highest LAI of 2.73 with a correction factor of 0.74 when compared to all surviving rice cultivars tested. Results of the study conformed with the findings of Tangpos (2018) that traditional upland rice cultivars attained higher LAI compared to improved upland rice cultivars due to their longer and broader leaves which achieved higher photosynthetic activity.

For fresh straw yield (t ha^{-1}), NSIC Rc27 significantly produced the heaviest straw of 4.27 tons ha^{-1}. On the other hand, the lowest straw yield was obtained in Black rice with 0.94 t ha^{-1}, but comparable with Caimpas, Red rice, Speaker, NSIC Rc192, and PSB Rc18. Ruales (2018) stated that fresh straw yield could be affected by the response of the said variety to the prevailing environmental conditions especially if it is exposed to intense heat at a longer period.

Root and Shoot Characteristics

Statistical analysis revealed that the number of nodal roots per plant, root dry weight, shoot dry weight, and root: shoot, ratio differed significantly among upland rice cultivars under rainfed lowland conditions (Table 4). Traditional upland rice cultivar Caimpas significantly produced more nodal roots (NRs) per plant of 739.67 roots compared to all rice cultivars except Black rice. On the other hand, Speaker produced a lesser number of nodal roots of 400.68 NRs. This implied that cultivars differed on the number of nodal roots due to its inherent differences in root characteristics and environmental adaptability (Bañoc *et al.*, 2000). For the root dry weight, Caimpas had the heaviest roots (81 g) comparable to PSB Rc18, Speaker, and Black rice. Lighter roots were produced by red rice (44.47 g), NSIC Rc192 (43.60 g), and NSIC Rc27 (38.57 g) cultivars. Heavy roots were attributed to the abundant number of nodal roots and longer root axis length resulting in higher root dry weight. The result of this study was construed to the findings of Grieneisen *et al.* (2007) that root development varied among cultivars due to its different adaptation abilities.

For the shoot parameter, Caimpas had a heavier shoot dry weight of 96.83 g followed by PSB Rc18, Speaker, and Black rice with 77.07 g, 75.70 g, and 66.30 g, respectively but not comparable with Red rice, NSIC Rc192, and NSIC Rc27. Relative to root: shoot ratio, PSB Rc18 (irrigated lowland variety-check) had the highest root: shoot ratio with 0.92 comparable with the other rice cultivars except for NSIC Rc27. Understanding the root characteristics of different rice cultivars was vital since according to Kondo et al. (2003), root characteristics were essential aspects for soil water and nutrient absorption for plant growth and development.

Table 4. Root and shoot characteristics of upland rice (*Oryza sativa* L.) cultivars under rainfed lowland conditions

Treatment	Number of nodal roots plant^{-1}	Root axis length plant^{-1} (cm)	Dry weight (g)		Root-shoot ratio
			Root	Shoot	
T_1 = Caimpas	739.67 ^{ab}	18.82	81.00 ^{a}	96.83 ^{a}	0.85 ^{ab}
T_2 = Black rice	713.67 ^{ab}	17.93	59.10 ^{ab}	66.30 ^{ab}	0.89 ^{ab}
T_3 = Red Rice	607.33 ^{bc}	16.76	44.47 ^{b}	53.97 ^{b}	0.83 ^{ab}
T_4 = Speaker	400.68 ^{e}	18.58	64.13 ^{ab}	75.70 ^{ab}	0.84 ^{ab}
T_5 = NSIC Rc192	475.00 ^{de}	17.22	43.60 ^{b}	52.97 ^{b}	0.82 ^{ab}
T_6 = PSB Rc18	579.33 ^{cd}	16.09	70.73 ^{ab}	77.07 ^{ab}	0.92 ^{a}
T_7 = NSIC Rc27	515.67 ^{cde}	16.34	38.57 ^{b}	49.33 ^{b}	0.78 ^{b}
Mean	575.90	17.39	57.37	67.45	0.85
C. V. (%)	7.99	6.67	19.75	20.72	5.03

Means within column followed by the same letter were not significantly different at 5 % level, HSD.

Yield and Yield Components and Harvest Index

Statistical analysis revealed that all yield and yield components and harvest index differed significantly among upland rice cultivars grown under rainfed lowland conditions (Table 5). Results showed that red rice cultivar significantly produced an abundant number of productive tillers (14.69 plant^{-1}) when compared to Speaker (3.53 tillers) and Caimpas (11.17 tillers) but comparable to Black rice, NSIC Rc192, PSB Rc18, and NSIC Rc27.

Relative to percent (%) filled spikelets per panicle, red rice (upland cultivar) remarkably obtained higher filled spikelets of 69.23% than Speaker with only 43.40% filled spikelets but comparable to all rice cultivars tested. For unfilled spikelets panicle^{-1}, the late-maturing upland rice cultivar Speaker obtained significantly higher percent unfilled spikelets of 56.60% compared to all rice cultivars, particularly red rice. On the other hand, PSB Rc18 (irrigated lowland rice variety, check), red rice, and Caimpas achieved a significantly heavier weight of 1,000 grains with 27.60, 27.23, and 27.20 g, respectively when compared to all rice cultivars except Black rice and NSIC Rc27.

Regarding grain yield (t ha^{-1}), NSIC Rc27 significantly produced the highest grain yield (6.74 t ha^{-1}) compared to all rice cultivars specifically Caimpas and Speaker with grain yields of 1.20 t ha^{-1} and 0.47 t ha^{-1}, respectively. NSIC Rc27, red rice, PSB Rc18, Black rice, NSIC Rc192 showed high tolerance on limitation of soil moisture during the entire growth and development of the crop since these performed relatively higher grain yields of 3.66 t ha^{-1}, 3.32 t ha^{-1}, 3.19 t ha^{-1}, and 1.87 t ha^{-1}, respectively. This conformed the study of Alou et al. (2017) stated that water stress particularly during the sensitive growth stage of the plant resulted in a low possibility of reducing grain production due to numerous productions of tillers and improved development of the root system.

Table 5. Yield and yield components and harvest index of upland rice (*Oryza sativa* L.) cultivars under rainfed lowland conditions

Treatment	No. of productive tillers $plant^{-1}$	Spikelets per panicle (%)		Weight of 1,000 grains (g)	Grain yield (t ha^{-1})	Harvest Index
		Filled	Unfilled			
T_1 = Caimpas	11.17 ^{b}	47.49 ^{ab}	52.51 ^{ab}	27.20 ^{a}	1.20 ^{d}	0.25 ^{b}
T_2 = Black rice	13.15 ^{ab}	60.23 ^{ab}	39.77 ^{ab}	23.80 ^{abc}	3.19 ^{bc}	0.36 ^{ab}
T_3 = Red Rice	14.69 ^{a}	69.23 ^{a}	30.77 ^{b}	27.23 ^{a}	3.66 ^{b}	0.41 ^{ab}
T_4 = Speaker	3.53 ^{c}	43.40 ^{b}	56.60 ^{a}	20.07 ^{c}	0.47 ^{d}	0.24 ^{b}
T_5 = NSIC Rc192	12.10 ^{ab}	60.23 ^{ab}	39.77 ^{ab}	21.27 ^{bc}	1.87 ^{cd}	0.34 ^{ab}
T_6 = PSB Rc18	11.93 ^{ab}	58.33 ^{ab}	41.67 ^{ab}	27.60 ^{a}	3.32 ^{bc}	0.38 ^{ab}
T_7 = NSIC Rc27	13.13 ^{ab}	64.40 ^{ab}	35.60 ^{ab}	25.93 ^{ab}	6.74 ^{a}	0.51 ^{a}
Mean	11.37	57.62	42.38	24.73	2.92	0.35
C. V. (%)	9.09	14.10	18.09	6.86	20.81	21.89

Means within column followed by the same letter were not significantly different at 5 % level, HSD.

For the harvest index, NSIC Rc27 (0.51) obtained a significantly higher harvest index compared to other rice cultivars except for Black rice, Red rice, NSIC Rc192, and PSB Rc18. The results of the study revealed that the highest grain yield of NSIC Rc27 was mainly attributed to an abundant number of productive tillers, higher filled spikelets, heavier weight of 1,000 seeds, and high harvest index. Besides, this cultivar was not severely affected by the ill-effects of limited soil moisture since lower grain yield was due to unfilled spikelets, and lower 1,000 seed weight. This conformed to the study of Price et al. (2002) that low grain productivity they observed in crops was a manifestation of a lesser number of productive tillers obtained and development of higher unfilled spikelets.

Cost and Return Analysis

The cost and return analysis of this study showed that NSIC Rc27 gave the highest gross margin of USD 1,823.16. This was followed by red rice, PSB Rc18, Black rice, and NSIC Rc192 with gross margins of USD 758.98, USD 644.31, USD 593.54, and USD 138.91 t ha^{-1}, respectively (Table 6). On the other hand, traditional upland rice cultivars, Caimpas, and Speaker generated negative gross margins of USD 91.94 and USD 348.89 t ha^{-1}. Relative to production cost, rice cultivars, namely: NSIC Rc27, red rice, PSB Rc18, and Black rice incurred higher production costs compared to the other rice cultivars since it increased higher expenditure relative to harvesting, threshing, cleaning, and drying of the said cultivars.

Table 6. Cost and return analysis of upland rice (*Oryza sativa* L.) cultivars under rainfed lowland conditions

Treatment	Grain Yield	Gross Income	Total variable cost	Gross Margin
	(t ha^{-1})	(USD ha^{-1})	(USD ha^{-1})	(USD ha^{-1})
T_1 = Caimpas	1.20	480.00	571.94	-91.94
T_2 = Black rice	3.19	1,276.00	682.46	593.54
T_3 = red rice	3.66	1,464.00	705.02	758.98
T_4 = Speaker	0.47	188.00	536.89	-348.89
T_5 = NSIC Rc192	1.87	748.00	609.09	138.91
T_6 = PSB Rc18	3.32	1,328.00	683.69	644.31
T_7 = NSIC Rc27	6.74	2,696.00	872.84	1,823.16

**Calculation of gross income is based on the current price of dried palay @ USD 0.40 kg^{-1}*

Conclusions

All agronomic characteristics of upland rice are significantly affected by the different cultivars evaluated. Traditional upland rice cultivars such as Perya, Remolites, Kalinayan-Monos, Tukoran, and Lebolebo are affected by low soil moisture resulting in severe wilting and death of plants and do not show tolerance to drought when these initially experience sufficient moisture at early vegetative growth. Root and shoot characteristics, yield, yield components, and harvest index of upland rice are remarkably influenced by the different rice cultivars tested. Traditional upland cultivar Caimpas produces abundant nodal roots, thus achieving the highest root and shoot dry weights as compared to other cultivars tested. NSIC Rc27, an improved upland rice variety, significantly produces a higher grain yield of 6.74 t ha^{-1} surpassing other high yielding rice cultivars such as red rice, PSB Rc18, and Black rice. This variety remarkably generates a higher gross income of USD 2,696.00 and a gross margin of USD 1,823.16.00 t ha^{-1} mainly due to the high productivity of grains.

Planting of improved upland rice variety NSIC Rc27 is recommended under rainfed lowland conditions especially when the growing field is exposed to a limitation of soil moisture and/or long dry spell. Other rice cultivars such as Black rice, red rice and PSB Rc18 (irrigated lowland variety) are also recommended as alternative rice cultivars for planting under rainfed lowland ecosystems.

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