



Agronomic Response of Local Upland Rice Cultivars on Growing under Two Cultivation Systems

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ABSTRACT

Background: This study aimed to observe the agronomic response of 18 Southeast Sulawesi local upland rice cultivars that were grown under two cultivation systems (dry land and wet rice field) and optimize local potential to support self-sufficiency and food security.

Methods: The research used a split-plot design with the following main plot: cultivation system (L) including upland (L1) and rice field cultivation system (L2). The subplots were 18 local upland rice cultivars such as Wangkomina (K1), Wuna Lapodidi (K2), Waburi-buri (K3), Wapantoga (K4), Nggalaru (K5), Wuna Parigi (K6), Bakala (K7), Biu (K8), Ikulaku (K9), Bou (K1), Momea (K11), Daindomorone (K12), Konkep (K13), Tinangge (K14), Ndoamoito (K15), Uwa (K16), Ndowatu (K17) and Indalibana (K18).

Result: The local upland rice responded better to the wetland cultivation system than the upland cultivation system. The local upland rice cultivar Ndowatu showed the highest production potential, which was statistically similar to the Biu, Ikulaku, Momea, Konkep and Uwa cultivars. Ndowatu cultivar showed high production potential (842.80 g.m⁻²). Thus, this cultivar can be considered suitable for development in the rainfed lowlands to increase the planting index and to support the self-sufficiency and food security of the region.

Key words: Cultivation system, Local upland rice, Planting index, Productivity, Rainfed rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the staple foodstuffs for most of the world's population (David *et al.*, 2020), including Indonesia. Crop management is the best alternative when area expansion is increasingly challenging and reduces productive land (Widjajanto *et al.*, 2021). Plant management includes nutrient and water management and planting methods, which increase rice production (Hussain *et al.*, 2018). Applying appropriate crop management techniques can increase yield components such as the number of panicles and grain per unit area, the rate of seed formation, the length of the panicles, 1000 grain weight and growth period (Wang *et al.*, 2017).

The existence of global climate change causes frequent drought in rice fields and dry land, reducing production and even failing to harvest, so an appropriate approach is needed in managing rice cultivation land. One of the efforts to overcome the lack of water supply in rice fields and dry land requires upland rice cultivars that provide good agronomic responses to both environmental conditions (Kumar *et al.*, 2017). To overcome these problems, identifying potential rice cultivars that have the opportunity to grow and produce maximal yield under both dry and wetlands conditions and at the same time identifying opportunities as genetic sources for new rice assembly traits (Nayaka *et al.*, 2021).

The rice cultivar is potential local upland rice widely cultivated by local farmers in Southeast Sulawesi, Indonesia. Differences in ecotypes and cultivation methods affect the phenological phase and duration of rice plant growth. The correlation between agronomic traits and yields depends on the ecotype of rice varieties. The optimal choice of

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cultivation technology to increase rice production sustainably depends on the variety and cultivation method (Li *et al.*, 2019). Therefore, the study aimed to explore the agronomic response of several local upland rice cultivars with high yield potential under both drylands with upland rice cultivation systems and paddy fields with lowland rice cultivation systems to ensure sustainable rice production food security of the region.

MATERIALS AND METHODS

The experiment was carried out from May to October 2017 in the experimental garden of the Faculty of Agriculture, University of Halu Oleo Kendari, Southeast Sulawesi, Indonesia (04000'4.59"S-122031'40.9"E and altitude of ±13.33 m above sea level). The average temperature was ranged from 23-29°C.

Plant materials

The plant material consisted of 18 local upland rice cultivars of Southeast Sulawesi, such as Pae Wangkomina, Waburi-buri and Wapantoga cultivars from North Buton Regency; Wuna Parigi and Wuna Lapodidi from Muna Regency; Nggalaru, Bakala, Bui, Ikulaku, Bou, Momea, Daindomoronene, Tinangge, Ndoamuito, Uwa, Ndowatu and Indalibana from Konawe Selatan District; and pae Konkep cultivar originating from Konawe Islands Regency.

Experimental design

The research used a split-plot design with three replications. The main plot was the cultivation system (L), which was divided into upland (L1) and rice field cultivation systems (L2). The subplots were 18 local upland rice cultivars such as Wangkomina (K1), Wuna Lapodidi (K2), Waburi-buri (K3), Wapantoga (K4), Nggalaru (K5), Wuna Parigi (K6), Bakala (K7), Bui (K8), Ikulaku (K9), Bou (K1), Momea (K11), Daindomoronene (K12), Konkep (K13), Tinangge (K14), Ndoamuito (K15), Uwa (K16), Ndowatu (K17) and Indalibana (K18). There were 72 experimental units comprised of two-factor combinations and three groups. Experiment plots with 20 plants were used as the experimental units.

Land preparation and data collection

Land preparation for the upland rice cultivation system was carried out by processing the soil into chunks, breaking the chunks, loosening the soil and forming beds and drainage channels. The land preparation for the rice field cultivation system was carried out by processing the soil into chunks, incubating for one week, silting and making a plot. The experimental plot size was 1×1 m, with a distance between treatments of 50 cm and between groups of 100 cm. The seeds that appeared in ±2 mm radicles were then planted on the upland and rice field cultivation system. The sources appeared radicles planted with a spacing of 25×25 cm, one seed per hole. Each plot contained 16 clumps of plants.

Fertilizer consist of 200 kg of Urea, 100 kg SP-36 and 100 kg of KCl per hectare. SP-36 and KCl fertilizers were applied at planting time. Urea was applied three times at

planting time, four and seven weeks after planting. Pest and disease were controlled optimally, while weeding was done manually using a hedgehog three and five weeks after planting. Irrigation in the rice field cultivation system was inundation. The condition of the land was in a chaotic state until three weeks after planting. During the formation of inundation, saplings were 0.5-1.0 cm high. During the vegetative growth phase to seed filling and maturation, the water height in the plots was ± 2 cm. Irrigation in an upland cultivation system depends on rainfall. The state of rain and soil fertility conditions were presented in Fig 1 and Table 1, respectively.

Observations were made on three clumps of sample plants. The variables observed were plant height, number of productive tillers, panicle length, total grain number, percentage of filled grain, 1000 grain weight, grain weight per clump, 50% flowering age and grain yield per plot and hectare.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) and Duncan multiple range test (DMRT) was performed to observe the differences in means using the SAS 9.2 test facility.

RESULTS AND DISCUSSION

The results showed that 50% flowering age and 90% yellowing of harvest age were strongly affected by the interaction of the growing system and cultivar treatment. Table 2 showed the fastest flowering age ($\alpha=0.05$) in the K7 cultivar in the rice field cultivation system at 93.67 days, 9 days faster than the upland cultivation system. The longest flowering age was found in the K6 cultivar in the upland cultivation system (124.67 days), slower than the rice field cultivation system. The average flowering age was generally fastest in the rice field cultivation system, except K8, K12 and K17 cultivars.

Age differences are influenced by genetic factors and environmental factors for upland rice growing. Upland rice cultivars that have good genetics showed faster flowering. Environmental factors such as water availability and optimal

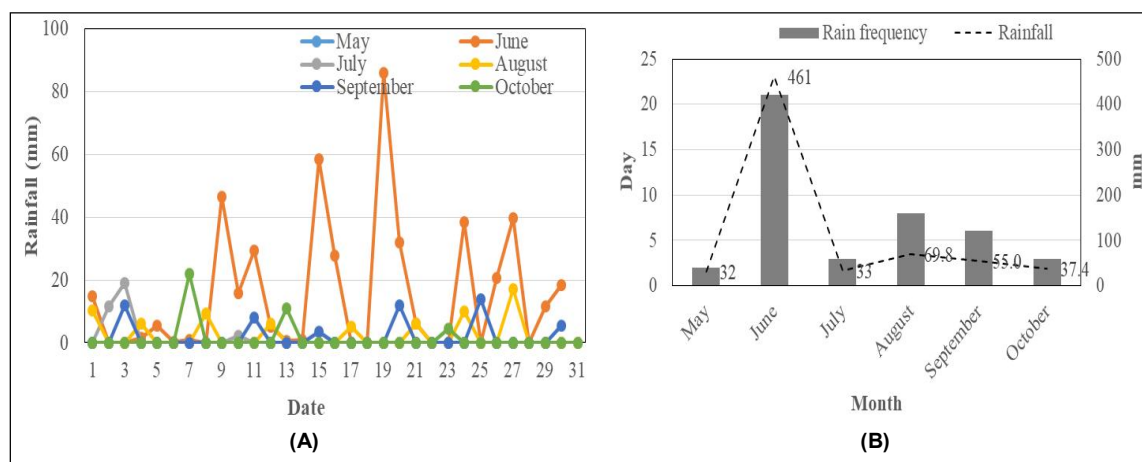


Fig 1: Distribution of (A) rainfall, (B) frequency and amount of monthly rainfall during the growth of local upland rice.

sunlight intensity play an essential role in the flowering and ripening of seeds (David *et al.*, 2020). Lack of water supply at the beginning of the generative phase, especially at flowering, causes the flowers not to develop because the insemination and anthesis phases are the most sensitive phases to water availability (Hussain *et al.*, 2018).

Table 3 showed that the highest plant height was obtained in the K16 cultivar (174 cm). Tian-yao *et al.* (2016) stated that the ideal plant height characteristics are 115-120 cm. The range of height for local upland rice cultivars was 149.7-174.0 cm. Various plant heights indicate that each

cultivar has different characteristics, genetics, morphology and physiology (Li *et al.*, 2019). The rice field cultivation system had the greatest effect on the average flag leaf area, wider than the upland cultivation system. K11 cultivar had the greatest influence on the average flag leaf area. The need for enough water for metabolic processes can cause the flag leaves to elongate and widen.

The highest productive tillers were found in the upland cultivation system (7.35 tillers). Pawar *et al.* (2016) classified productive tillers into five categories: very few (5 tillers per plant), few (5-9 tillers per plant), moderate (10-19 tillers per plant),

Table 1: Soil physicochemical condition of the study site.

Parameter	Value		Unit
	Lowland	Upland	
pH (H ₂ O)	6.87	6.68	
SOC	1.65	1.33	%
Total N	0.08	0.05	%
P ₂ O ₅ (HCl 25%)	35.02	19.22	mg/100 g
K ₂ O (HCl 25%)	14.13	10.38	mg/100 g
Al-dd (KCl 1N)	0.307	0.51	cmol(+)/kg
Ca-dd (eks Amonium Acetat 1N pH 7)	6.32	2.18	cmol(+)/kg
Mg-dd (eks Amonium Acetat 1N pH 7)	6.09	5.49	cmol(+)/kg
K-dd (eks Amonium Acetat 1N pH 7)	0.040	0.014	cmol(+)/kg
Na-dd (eks Amonium Acetat 1N pH 7)	6.43	7.59	cmol(+)/kg
CTC (eks Amonium Acetat 1N pH 7)	17.24	18.59	cmol(+)/kg

Source: Laboratory of Soil Science, Faculty of Agriculture, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia.

Table 2: The effect of the interaction of the cultivation system and cultivar treatment on flowering age 50% (days).

Cultivar treatment	Flowering age 50% (days)		Average
	Cultivation system		
	Upland rice (L1)	Rice field (L2)	
Wangkomina (K1)	102.67 ^{de} _p	100.33 ^{abcd} _q	101.50 ^{bcd} _e
Wuna Lapodidi (K2)	106.33 ^{cd} _p	103.67 ^a _q	105.00 ^{bc}
Waburi-buri (K3)	106.33 ^{cd} _p	103.33 ^{ab} _q	104.83 ^{bc}
Wapantoga (K4)	99.67 ^{ef} _p	95.33 ^{def} _q	97.50 ^{ef}
Nggalaru (K5)	107.33 ^{bc} _p	96.33 ^{cdef} _q	101.83 ^{bcd} _e
Wuna Parigi (K6)	124.67 ^a _p	99.67 ^{abcde} _q	112.17 ^a
Bakala (K7)	102.67 ^{de} _p	93.67 ^f _q	98.17 ^{ef}
Biu (K8)	95.00 ^f _p	96.00 ^{def} _p	95.50 ^f
Ikulaku (K9)	112.00 ^b _p	101.67 ^{abc} _q	106.83 ^b
Bou (K10)	100.00 ^e _p	95.00 ^{def} _q	97.50 ^{ef}
Momea (K11)	100.33 ^e _p	93.67 ^f _q	97.00 ^{ef}
Daindomoronene (K12)	101.00 ^{de} _p	99.67 ^{abcde} _p	100.33 ^{cdef}
Konkep (K13)	101.67 ^{de} _p	96.67 ^{cdef} _q	99.17 ^{def}
Tinangge (K14)	103.67 ^{cde} _p	94.33 ^{ef} _q	99.00 ^{def}
Ndoamuito (K15)	102.67 ^{de} _p	100.33 ^{abcd} _q	101.50 ^{bcd} _e
Uwa (K16)	100.33 ^e _p	97.33 ^{cdef} _q	98.83 ^{def}
Ndowatu (K17)	99.33 ^{ef} _p	98.00 ^{bcd} _p	98.67 ^{def}
Indalibana (K18)	108.00 ^{bc} _p	99.33 ^{abcde} _q	103.67 ^{bcd}
Average	104.09 ^p	98.02 ^q	

Note: The numbers followed by different notations in the same column (a,b,c,d,e,f,g,h) and the same row (p,q) are significantly different at DMRT $\alpha=0.05$.

many (20-25 tillers per plant) and very many (>25 tillers per plant). High inundation for an extended period of time must be avoided during the tiller formation phase because it can suppress the increase in the number of tillers by inhibiting the physiological and morphological activity of shoot formation. K4 and K9 cultivars had the greatest number of productive tillers ($\alpha=0.05$). According to the study findings, the average number of productive tillers from each upland rice cultivar remained low.

K16 cultivar had the greatest panicle length, with an average of 38.67 cm. Based on average panicle length observations, K1, K2, K3, K4 and K6 cultivars belong to the longest panicle category (>30 cm). In comparison, the K4 cultivar belongs to the moderate panicle category (20-30 cm). The variation in panicle length is due to genetic factors and environmental impacts that can cause variability in the panicle length of several local upland rice cultivars (Li *et al.*, 2019). Table 4 showed that the rice field cultivation system produced a total grain, higher than the upland cultivation system ($\alpha=0.05$). A good microclimate environment increases relative humidity. A significant decrease in canopy temperature during periods of high temperature under inundation conditions indicates that stronger transpiration increases high-temperature stress resistance and increases the rate of photosynthesis significantly (Liu *et al.*, 2011).

K17 cultivar produced 350.2 grains, higher than the K1 cultivar (141.67 grains). According to Tian-yao *et al.* (2016),

the number of grains per panicle of around 150 grains is the criterion for higher yields. All cultivars were classified as very good based on the amount of grain obtained. The yield components are determined by the interaction of the genotype and its response to environmental conditions. Grain yield and yield components were strongly influenced by planting time, location and genotype.

The rice field cultivation system showed the maximum percentage of filled grain (88.14%) than the upland cultivation system (74.52 %). The percentage of filled grains was affected by the width of the flag leaves in the rice field cultivation system (Table 3). According to Fatima *et al.* (2019), the wider the flag leaf, the greater the allocation of photosynthate to seeds, resulting in a high number of filled grains and weight of 1000 grains in the rice field cultivation system. Rice field cultivation produced the highest grain weight of 1,000 grains, at 27.98 g. The highest percentage of filled grain was obtained in the K8 cultivar (93.70%). Environmental and plant genetic factors influence the formation of filled grains (Li *et al.*, 2019), resulting in a wide range of percentages of filled grains.

K1 cultivar had the highest weight of 1000 grains (39.00 g). Because it affects the size and shape of the upland rice grain, the weight of 1000 grains is closely related to panicle length and total grain quantity. The larger the grain size, the greater the grain weight produced and vice versa, the smaller the grain size, the lower the grain weight produced (Saragih and Wirnas, 2019). The Ndowatu cultivar had the greatest

Table 3: The effect of cultivation systems and cultivars on plant height at harvest, flag leaf area, number of productive tillers and panicle length.

Treatment	Variable observation			
	Plant height (cm)	Flag leaf area (cm ²)	Number of productive tillers	Panicle length (cm)
Cultivation systems				
Upland rice	152.29	47.66 ^b	7.35 ^a	30.60
Rice field	162.83	67.01 ^a	5.17 ^b	32.03
Cultivars				
Wangkomina (K1)	149.56 ^d	58.28 ^{bcd}	4.89 ^f	36.59 ^{ab}
Wuna Lapodidi (K2)	151.22 ^{cd}	47.23 ^{def}	5.33 ^{ef}	31.36 ^{cdef}
Waburi-buri (K3)	151.96 ^{cd}	58.74 ^{bcd}	4.89 ^f	32.45 ^{bcd}
Wapantoga (K4)	166.29 ^{ab}	60.08 ^{abcd}	8.06 ^a	32.37 ^{bcd}
Nggalaru (K5)	158.96 ^{bcd}	51.22 ^{cde}	5.22 ^{ef}	33.09 ^{bcd}
Wuna Parigi (K6)	166.36 ^{ab}	35.64 ^e	5.61 ^{def}	23.36 ⁱ
Bakala (K7)	155.76 ^{bcd}	67.27 ^{ab}	6.00 ^{bcd}	35.98 ^{abc}
Biu (K8)	153.47 ^{cd}	42.36 ^{ef}	7.72 ^{ab}	25.13 ^{ghi}
Ikulaku (K9)	150.45 ^{cd}	59.27 ^{abcd}	8.00 ^a	33.28 ^{bcd}
Bou (K10)	161.27 ^{bc}	69.25 ^{ab}	5.33 ^{ef}	34.48 ^{abcd}
Momea (K11)	158.18 ^{bcd}	73.46 ^a	5.06 ^f	37.01 ^{ab}
Daindomoronene (K12)	160.06 ^{bcd}	44.11 ^{ef}	6.50 ^{abc}	24.73 ^{hi}
Konkep (K13)	156.56 ^{bcd}	62.63 ^{abc}	6.44 ^{abc}	29.87 ^{defg}
Tinangge (K14)	153.42 ^{cd}	62.72 ^{abc}	5.83 ^c	27.74 ^{fghi}
Ndoamito (K15)	156.59 ^{bcd}	51.06 ^{cde}	7.22 ^{abcd}	25.94 ^{ghi}
Uwa (K16)	174.00 ^a	71.83 ^{ab}	7.00 ^{abc}	38.67 ^a
Ndowatu (K17)	149.67 ^d	64.18 ^{abc}	7.61 ^{abc}	33.19 ^{bcd}
Indalibana (K18)	156.68 ^{bcd}	52.73 ^{cde}	5.94 ^{bcd}	28.50 ^{efgh}

Note: The numbers followed by different letters are significantly different at DMRT $\alpha=0.05$.

Table 4: The effect of cultivation systems and cultivars on the total number of grains per panicle, percentage of filled grains, 1000 grain weight, grain weight per clump and grain production per square meter.

Treatment	Variable observation				
	Total number of grains per panicle (grain)	Percentage of filled grains (%)	1000 grain weight (g)	Grain weight per clump (g)	Grain production per square meter (g.m ⁻²)
Cultivation systems					
Upland rice	173.61 ^b	74.52 ^b	26.24 ^b	19.60 ^b	392.00 ^b
Rice field	230.10 ^a	88.14 ^a	27.98 ^a	24.60 ^a	492.00 ^a
Cultivars					
Wangkomina (K1)	141.67 ^f	76.68 ^c	39.00 ^a	18.40 ^{cde}	368.00 ^{cde}
Wuna lapodidi (K2)	152.37 ^f	78.86 ^{bc}	27.05 ^{cde}	15.00 ^{de}	300.00 ^{cde}
Waburi-buri (K3)	148.14 ^f	75.37 ^c	32.76 ^b	17.48 ^{cde}	349.60 ^{cde}
Wapantoga (K4)	170.95 ^{def}	76.76 ^c	29.69 ^{bc}	24.04 ^c	480.80 ^{cde}
Nggalaru (K5)	239.81 ^{bc}	85.49 ^{abc}	25.30 ^{cdef}	20.12 ^{cde}	402.40 ^{de}
Wuna Parigi (K6)	144.87 ^f	74.34 ^c	22.03 ^{ef}	11.94 ^e	238.80 ^e
Bakala (K7)	207.54 ^{cde}	86.26 ^{abc}	27.54 ^{cd}	22.54 ^{cd}	450.80 ^{de}
Biu (K8)	171.94 ^{def}	93.70 ^a	27.96 ^{bcd}	24.53 ^c	490.60 ^{abcd}
Ikulaku (K9)	175.28 ^{def}	85.05 ^{abc}	26.59 ^{cde}	23.87 ^c	477.40 ^{abcd}
Bou (K10)	211.15 ^{bcd}	82.40 ^{abc}	25.71 ^{cdef}	18.21 ^{cde}	364.20 ^{bode}
Momea (K11)	224.36 ^{bc}	73.84 ^c	28.51 ^{bcd}	20.93 ^{cd}	418.60 ^{abc}
Daindomoronene (K12)	164.16 ^{ef}	86.39 ^{abc}	28.10 ^{bcd}	19.74 ^{cde}	394.80 ^{cde}
Konkep (K13)	221.53 ^{bc}	82.18 ^{abc}	26.84 ^{cde}	25.65 ^{bc}	513.00 ^{abcd}
Tinangge (K14)	229.07 ^{bc}	81.04 ^{abc}	23.77 ^{def}	21.49 ^{cd}	429.80 ^{bcd}
Ndoamoito (K15)	201.06 ^{cde}	75.18 ^c	24.72 ^{cdef}	21.64 ^{cd}	432.80 ^{bode}
Uwa (K16)	256.13 ^b	80.18 ^{abc}	27.43 ^{cde}	32.77 ^b	655.40 ^{ab}
Ndowatu (K17)	350.20 ^a	91.54 ^{ab}	20.91 ^f	42.14 ^a	842.80 ^a
Indalibana (K18)	223.18 ^{bc}	78.67 ^{bc}	24.09 ^{def}	17.29 ^{cde}	345.80 ^{de}

Note: The numbers followed by different letters are significantly different at DMRT $\alpha=0.05$.

effect on grain weight per clump. The number of tillers, panicle length, filled grains and 1000 grains all impact grain weight per hill. The grain weight per hill increases as the yield components increase.

The high production of unhulled rice per hill in the rice field cultivation system has implications for the increased grain production per hectare. In the rice field cultivation system, the production of unhulled rice per square meter was 492.00 g, higher than the upland cultivation system ($\alpha=0.05$). Compared to other environmental factors, the availability of water for plants can affect plant growth. When the groundwater content was kept at 60% of its water holding capacity (WHC), the grain yield decreased significantly compared to stagnant conditions.

In contrast to the upland cultivation system (dry land), water needs are limited because rice growth is solely dependent on rainfall. Drought-affected areas have significantly less dry matter accumulation during flowering and maturity (Kumar *et al.*, 2018). As a result, local upland rice production is lower in dryland with upland cultivation systems than rice fields. The Ndowatu or K17 cultivar showed the highest effect of cultivars on grain yield per hectare. The contribution of yield components cannot be separated from the high and low yields of upland rice. The length of the panicle determines the amount of grain

produced. According to Saragih and Winas (2019), the longer the panicles are, the more grain is generated, increasing grain yield.

Different soil chemical fertility conditions produced the variation in growth and production of local upland rice among lowland and upland cultivation systems (Table 1). Lowland cultivation systems have higher nutrient content than upland cultivation systems, such as C, N, P₂O₅, K₂O, Ca-dd, Mg-dd and K-dd. Therefore, all cultivars had earlier flowering ages (Table 2) and the components of production and grain production (Table 4) were higher in the lowland cultivation system than in the upland cultivation system.

CONCLUSION

Local upland rice showed an excellent response to the rice cultivation system compared to the upland cultivation system. The cultivars cultivated with the rice field cultivation system had a faster flowering age than the upland cultivation system. Local upland rice cultivar Ndowatu is a cultivar that has a high production potential (842.80 g m⁻²). Cultivars with good responses to various cultivated land conditions can be developed in rainfed lowlands to increase the planting index. The diversity of growth components, production components and local upland rice production is great

potential as a genetic source for future rice assembly for high yield potential, drought tolerance and wider adaptability.

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