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Genotypic response to weeding regimes of upland rice on woodland savannah sub-ecological area of Lake Albert crescent zone of Uganda

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Weeds represent one of the major biological constraints to upland rice production in low input agricultural systems. The effects of weeding regimes and rice cultivars on weed growth and rice yield were investigated over three seasons. Four weeding regimes [0 (no weeding control), 1, 2, and 3] and three popular rice varieties (NARIC 2, a local cultivar, and NERICA 4), were tested in 4x3 factorial experiment in a Randomised Complete block with three replicates. The most important weed species recorded were; *Biden pilosa, Commelina benghalensis* L., *Euphorbia hirta* L., *Micrococca mercurialis* Benth., *Galisonga parviflora* Cav, *Sida rhombifolia* L., *Triumfeta* spp*, Guizotia scabra, Celocia trigyna, Cyprus rotundus, Panicum Maximum Jacq,* and *Imperata cylindrica* L. Across cultivars, the best weeding regimes for weed control and rice yields were single weeding and weeding twice. Differences among interaction effects between variety and weeding regime were not significant for most traits, except ripening ratio and grain yield in experiment one and experiment two. Across weeding regimes, NERICA 4 out yielded the other varieties in all the three experiments. However, a single well timed hand hoe weeding, together with the use of a cultivar with good adaptation to unfavourable rice growing conditions, such as NERICA 4, would increase land and labour productivity of upland rice-based systems in Uganda.

Key words: Genotype, rice, upland, weeding regimes, yield.

INTRODUCTION

Rice currently ranks as the second most important cereal in Uganda after maize (Anyanga, 2015). Over the last 10 years, production of this crop has more than doubled owing to the expansion of the rice production areas to upland ecology. In addition, the introduction and promotion of upland rice varieties dubbed NERICA (2005 to 2015) has resulted into large scale production of the crop. Indeed, upland rice covers close to 70% of the total area under rice cultivation in the country (Mohamed, 2012). In spite of these developments, the country is still considered a net rice importer, and will perhaps continue unless domestic production increases remarkably to counter the demand by the growing urban population (World Bank, 1993; Hyuha, 2006; Mohamed, 2012). NERICA's potential yield in sub-Saharan Africa is 5 t/ha; with fertiliser application. However, farmer field conditions in Uganda give a yield of 1.5 t/ha according to several reports (Imanywoha, 2001; Otsuka and Kalirajan 2006). This clearly undermines the status of rice as an important food security and income crop in Uganda. Several reports have highlighted the major causes of this yield gap (Odogola et al., 2006; Hyuha et al., 2007; Kaizzi et al., 2014). Among these, failure to manage weeds and low soil fertility are central to the problem.

Uninhibited weed growth among crops is estimated to cause yield losses in the range of 48 to 100% (Akobundu, 1980; Becker and Johnson, 2001; Johnson et al., 2004; Toure et al., 2013). Specifically, weeds compete severely with rice plants for space, nutrients, air, water and light adversely affecting plant height, leaf architecture, tillering habit, shading ability, growth pattern and crop duration (Miah et al., 1990). In addition, weeds depress the normal yield of grains per panicle and grain weight (Bari et al., 1995). Therefore, a higher rice yield should be a motivation for maintaining a weed free rice crop environment.

Rice is categorised as a weak weed competitive crop. However, several studies have reported the existence of genetic variation in weed competitiveness among rice cultivars (Fofana and Rauber, 200; Haefele et al., 2004; Rodenburg et al., 2009; Saito et al., 2010). Weed competiveness comprises weed tolerance, the ability to maintain high yields despite weed competition, and weed suppressive ability, the ability to suppress weed growth and reduce weed seed production (Zhao et al., 2006a). The number of weed competitive cultivars with high adaptation to African agro-ecosystems reported to date is limited (Wopereis et al., 2008; Rodenburg and Johnson, 2009).

To reduce the effects of weed pressure on crop yields, most upland rice farmers rely largely on pre- and postharvest fires, preparation, and hand or hoe weeding of fields. Labour-intensive hand weeding is often preferred by farmers because the use of herbicides use is costly, and low literacy rates among farmers in Uganda, like the rest of SSA, further limits herbicide use (Rodenburg and Johnson, 2009). As such, labour availability for weed control becomes limited as weeds multiply with cropping season, resulting into high levels of yield reduction (Saito and Futakuchi, 2014). However, the most commonly accepted approach to manage weeds is to follow an integrated weed management strategy comprising the combined use of two or more available and effective technologies (Sanyal et al. 2008). Often rice farmers in the uplands of Uganda weed two to three times (by hand or hoe) during the rice growing season, depending on the weed pressure (Alou et al., 2012; Anyanga, 2015). Such weeding interventions should, however, be well timed to optimize weed suppression, grain yield (Dzomeku et al. 2007; Ekeleme et al. 2009), and the time available for the farmer to attend to other non-farm activities (Alou et al., 2012). Therefore, the identification of superior weed competitive rice genotypes would be an attractive, cost effective and safe approach for sustaining rice productivity, particularly for resource-constrained farmers. Weed competitive genotypes would be part of an integrated weed management strategy. The ideal weed competitive genotypes are high yielding under both weedy and weed-free conditions. Therefore, the purpose of this study was to (i) investigate the effect of weeding regimes across popular upland rice varieties and (ii) determine the most weed competitive upland rice variety in the Lake Albert crescent zone of Uganda.

MATERIALS AND METHODS

Description of the study site characteristics

Three upland rice experiments were conducted over 3 years (2012 to 2014) at Bulindi Zonal Agricultural Research and Development Institute (BUZARDI) located in the Lake Albertine Crescent Zone of

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Uganda. The three experiments were conducted in different fields within the research station. This station lies on average longitudes 312954 N and latitudes 12950 E. This institute receives a bimodal rainfall (March to June and August to December) and average rainfall was 1000 mm per year. This experimental site is located in Hoima district which is one of the leading Upland rice producing districts in Uganda (Lodin, 2005). The vegetation in the area is dominantly savannah with short and tall grasses and shrubs with widespread bush burning practiced (Lodin, 2005). Soils in the area are classified as acidic ferralsols (FAO System, 2004) with low exchangeable bases and organic matter. They are dominantly clay (heavy textured), acidic and low particularly in available phosphorus and total nitrogen.

Soil analysis data based on Alou et al. (2012) found that the soils in this experimental station are typically clay loam with sand content of less than 45%. The mean soil pH is below the critical value of 5.2 and below the range of 5.5 to 6.5 considered favorable for plant nutrition. In addition, the mean values of available phosphorus, total nitrogen and exchangeable bases were found to be low.

Experimental design, crop management and data collection

For the study of genotypic response to weeding regimes, a 4 x 3 factorial experiment was established based on randomized complete block design with three replications, and weeding regime and rice variety as factors at four and three levels, respectively. The four levels of weeding regimes were; 1 hoe weeding at 21 days after sowing (DAG), 2 hand hoe weeding at 21 DAG and 42 DAG, and three hand hoe weeding at 21, 42 and 63 DAG, and a no weeding control, while the three levels of rice variety as popular upland rice varieties were; NERICA 4, NARIC2 and Local variety). The plots were of dimensions 5.0 m long × 2.1 m wide. No fertilizers and/or pesticides was applied in this trial. A seeding rate of 50 kg/ha was used to estimate the seed requirement for the trial plots. Seed were dibbled manually in hills 12.5 cm between hills and 30 cm between rows. Sowing was done by the second week of August in each year while harvesting was done by end of November of each year.

Data collection

Data were collected on number of panicles, number of spikelets, spikelet sterility, 1000-grain weight and yield at harvest.

Data analysis

The data collected were subjected to analysis of variance to determine whether the mean squares due to weeding regimes were significant using Genstat version 14 (Payne et al., 2011). An analysis of variance was performed for each trait in each season using ANOVA in Genstat (Payne et al., 2011). Each season (experiment) was analysed separately because experiment × weeding regime × variety interaction was significant. The ANOVA of each experiment was followed by pairwise comparisons using the least significant differences (LSD), when the F-test for the treatment effect was found significant ($P \leq 0.05$).

Broad-sense heritability (H) was used to evaluate the stability of performance for rice yield components *via* estimation of repeatability across replications. The higher the value of H, the greater the genetic stability. H was estimated for rice yield components for each weed treatment for each season, and calculated from variance components, as:

$$H = \frac{\sigma^2 v}{(\sigma^2 v + \sigma e^2 / r)}$$

Where, $\sigma^2 v$ and σe^2 are variety and within – experiment error variances, respectively, and r is the number of replicates. Variance components were estimated using Genstat version 14 (Payne et al., 2011). The estimate of H was biased upward by confounding of variety and variety by experiment variances, but beneficial in approximately comparing the precision for different weed treatments (Zhao et al., 2006b).

RESULTS

Dominant weed species associated with upland rice fields in the Lake Albert crescent zone of Uganda

Several weed species were encountered in this study. These were composed of both broad leaf and grass species. However, their relative abundances depended on the weeding regime applied and previous land use (Nagasawa et al., unpublished). Table 1 shows the major weed species encountered in the fields.

The effect of weeding regimes on selected agronomic traits in rice varieties in the Lake Albert crescent zone of Uganda

In Experiment 1 (second season of 2012 or 2012B), significant differences among weeding regimes were observed for number of panicles per m^{-2}, number of spikelets per panicle and ripening percentage ($P<0.05$ to $P<0.001$) (Table 2). Varietal differences were not significantly ($P>0.05$) different, except number of spikelets per panicle. The differences among interaction effects of weeding regime × variety were not significant ($P > 0.05$) for most traits (Table 2). The number of panicle per $metre^{-2}$ (ranged from 149 to 310), number of spikelets per panicle (ranged from 33 to 67), and ripening ratio (ranged from 12.5 to 44.5%) had 254, 52 and 23% as

Table 1. Major weed species identified from upland rice fields in the Lake Albert crescent zone of Uganda.

Scientific names	Common/English name	Special attribute
Broad leaf weeds		
Biden pilosa	Black jack	Very abundant in crop fields, and highly competitive producing a lot of seed.
Commelina benghalensis L.	Day flower, Bengal spiderwort, Wandering jew	An alternate host of plant pathogens and nematodes
Euphorbia hirta L.	Garden spurge, milk weed, asthma-plant	An early colonizer of bare lands, Common weed in upland rice fields and has a wide native range
Micrococca mercurialis Benth	-	Has high native range, used as a vegetable in some parts of Uganda
Galisonga parviflora Cav.	Gallant soldier	Prolific weed with a short life cycle
Sida rhombifolia L.	Queensland hemp	Has high native range
Triumfeta spp		Notorious weed with high native range and reproductive potential
Guizotia scabra	-	Notorious weed in farmlands where it is unknown. Can withstand flooding.
Celocia trigyna	Wool flower	In some parts of Africa, its eaten as vegetable, it also has anthelmintic properties in humans, elsewhere, it's a weed. Competitive with crops for water and soil nutrients
Grass species		
Cyprus rotundus	Purple nutsedge	Highly competitive with crops for both soil nutrients and moisture.
Panicum Maximum Jacq.	Guinea grass	Domesticated as a forage, otherwise becomes weed in crop fields.
Imperata cylindrical (L.)	Spear grass	Highly dominant and competitive weed species

Sources of species description: (Terry and Michieka, 1987; Promotion of Rice Development Project, 2012).

Table 2. Mean squares for the combined analysis of effect of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2012 in the Lake Albert crescent zone of Uganda.

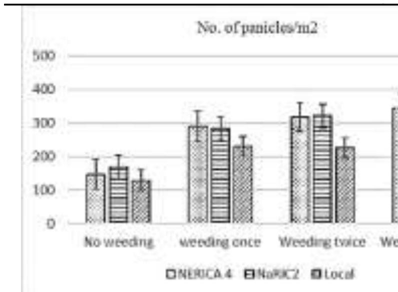
Source of variation	DF	1000 grain wt	Plant height	No. of panicles per m^2	No of spikelet per panicle	Ripening percentage (%)	Yield
Weeding regime	3	0.13543**	0.002418ns	0.210276**	0.16704***	0.8779**	0.4165ns
Variety	2	0.04623ns	0.003000ns	0.042475*	0.02919ns	0.0486ns	0.1638ns
Weeding regime × Variety	6	0.07183ns	0.001191ns	0.003310ns	0.01214ns	0.0405ns	0.1013ns
Residual	22	0.08445	0.001223	0.009256	0.02036	0.1427	0.2195
Total	35						

Ns = not significant; * = significant at P<0.05; ** = significant at P<0.01; *** = Significant at P<0.001; DF = degrees of freedom.

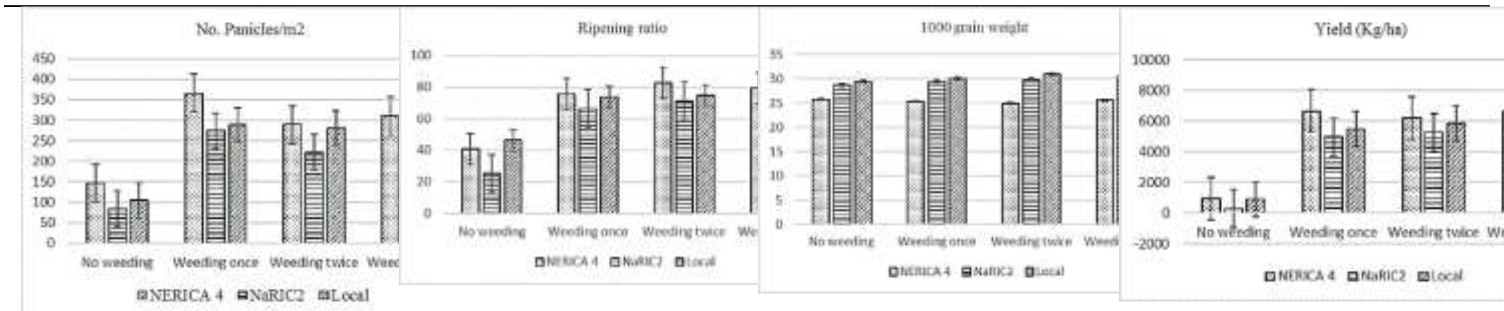
average trait scores for each weeding regime respectively (Table 5). Across varieties, number of panicles per metre^{-2} (ranged from 34 to 83) with an average trait scores of 61 for variety NERICA 4; ranged from 34 to 62 an average traits score of 62 for NaRIC 2; ranged from 30 to 66 had an average traits score of 48 for Local variety (Figure 1).

In Experiment 2 (second season of 2013 or 2013B),

Experiment1



Experiment 2



Experiment 3

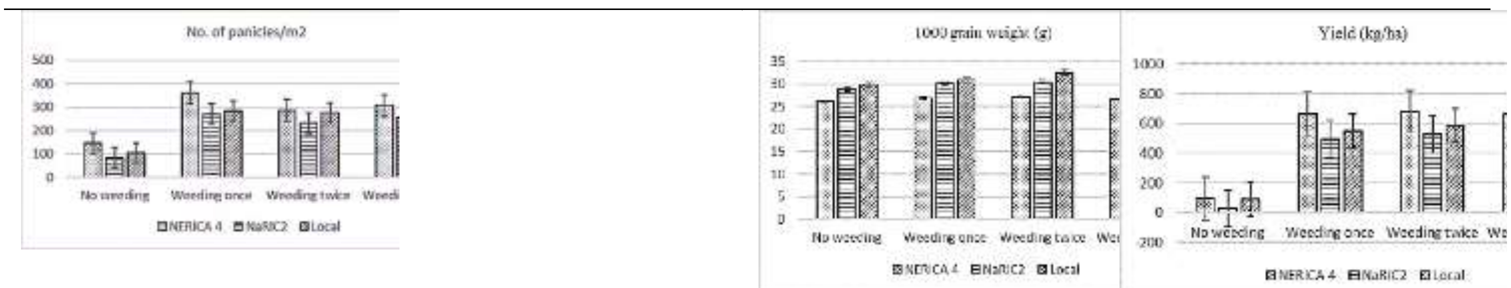


Figure 1. The effect of weeding regime on selected agronomic traits by variety for second seasons 2012, 2013 and 2014 in the Lake Albert crescent zone.

Table 3. Mean squares for the combined analysis of effect of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2013 in the Lake Albert crescent zone of Uganda.

Source of variation	DF	1000 grain weight	Plant height	Number of panicles per m^2	Number of spikelet per panicle	Ripening percentage (%)	Yield
Weeding regime	3	1.242ns	437.15***	67826.0***	3991.7***	3213.76***	2.15302***
Variety	2	81.819***	110.43ns	15167.0***	354.3ns	261.81*	0.12741***
Weeding regime × Variety	6	0.978ns	29.65ns	1242.0ns	252.7ns	111.69*	0.04847**
Residual	22	1.343	41.64	1127.0	220.6	52.44	0.01220
Total	35						

Ns = not significant; * = significant at P<0.05; ** = significant at P<0.01; *** = Significant at P<0.00; DF = degrees of freedom.

significant differences among weeding regimes were observed for plant height, number of panicles per m^{-2}, number of spikelets per panicles per metre squared, ripening percentage and yield (P<0.05 to P<0.001). Significant differences in variety responses were observed for 1000 grain weight, number of panicles per m^{-2}, ripening percentage and yield (P<0.05 to P<0.001) (Table 3). The differences among interaction of weeding regime × variety interaction was significant for only ripening percentage and yield (P<0.05 to P<0.01) (Table 3). The number of panicle per m^{-2} (ranged from 112 to 310), number of spikelets per panicle (ranged from 56 to 105), ripening percentage (ranged from 37.5 to 76.9), plant height (ranged from 78.4 to 95.3 cm) and yield (ranged from 714 to 5786 kg/ha) had 239, 87, 66%, 88 cm, 4449 kg/ha as the average trait scores for each weeding regime respectively (Table 6).

Across rice varieties, number of panicles per metre^{-2} (ranged 275 from to 361) with an average trait score of 275 for NERICA 4; ranged 83 from to 271 and an average traits score of 211 for NaRIC2; ranged from 103 to 284 with an average trait score of 225 for Local. The 1000 grain weight scores ranged from 26.13 to 27 g with a variety average score of 26.7 g for NERICA 4; ranged from 28.87 to 31.1 g with an variety average of 30.1 g for NaRIC 2, ranged from 29.93 to 32.53 g with a variety average of 31.1 g for Local variety. The ripening percentage scores ranged from 40.9 to 82.9 g with a variety average score of 69.2 g for NERICA 4, ranged from 25.4 to 79.4 g with a variety average of 63.2 g for NaRIC 2; ranged from 46.3 to 74.5 g with a variety average of 66.6 g for local variety (Figure 1).

In Experiment 3 (second season of 2014B or 2014B), significant differences among weeding regimes were observed for all traits measured (P<0.05 to P<0.001) (Table 4). Varietal differences were significantly different for 1000 grain weight, number of panicles per metre^{-2}, and yield (P<0.01 to P<0.001). The differences among interaction of weeding regime x variety was not significant for all traits (P>0.05) (Table 4). The number of panicles per m^{-2} ranged from 111 to 306, number of spikelets per panicle ranged from 56 to 105, 1000 grain weight ranged from 28.31 to 30.01 g, plant height ranged from 66.9 to 86.9 cm, ripening percentage ranged from 37.5 to 76.9% and yield had 237, 86, 29, 81, 66.3%, and 438 kg/ha as average trait scores for each weeding regime respectively (Table 7).

Across varieties, number of panicles per m^{-2} ranged from 145 to 308 with an average trait scores of 275 for NERICA 4; ranged from 83 to 271 with an average traits score of 211 for NaRIC 2; ranged from 103 to 284 g with an average trait score of 224 for local variety. The 1000 grain weight ranged from 26.3 to 27.0 with an average trait score of 26.7 g for NERICA 4; ranged from 28.87 to 31.07 with an average traits score of 30.1 g for NaRIC 2; ranged from 29.93 to 32.53 g with an average trait score of 31.1 g for local variety. The yield (ranged from 96 to 666) with an average trait scores of 527 kg/ha for NERICA 4; ranged from 29 to 542 kg/ha an average traits score of 3398.5 kg/ha for NaRIC 2; ranged from 90 to 587 kg/ha with an average trait score of 423 kg/ha for local variety as (Figure 1).

Overall, there were increases in the trait responses with each weeding regime and the extent of increases varied by trait and also by season (Tables 5, 6, and 7). In addition, varietal responses also varied with traits and seasons (Figure 1).

Results of broad sense heritability estimation for three upland varieties across weeding treatments are presented in Table 8. Heritability was lower where weeding was done compared to plots where no weeding was conducted for ripening percentage and plant height in all experiments, and for plant height only in Experiment 1.

Table 4. Mean squares for the effect of combined analysis of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2014 in the Lake Albert crescent zone of Uganda.

Source of variation	DF	1000 grain weight	Plant height	Number of panicles per m^2	Number of spikelet per panicle	Ripening percentage (%)	Yield
Weeding regime	3	0.0009783*	0.027638**	0.379434**	3929.5**	0.239639**	2.15269**
Variety	2	0.014444388**	0.000249ns	0.060685**	384.6ns	0.013891ns	0.13560**
Weeding regime × Variety	6	0.0001640ns	0.001894ns	0.006913ns	284.9ns	0.016127*	0.04573*
Residual	22	0.0002708	0.001841	0.005060	267.9	0.004634	0.01313
Total	35						

Ns = not significant; * = significant at P<0.05; ** = significant at P<0.01; *** = Significant at P<0.001; DF = degrees of freedom.

The heritability for 1000 grain weight, number of panicles per metre squared, number of spikelets per panicle was similar across weed treatments in all experiments, except where weeding was done once in Experiment 2, which had a lower heritability. In contrast, heritability for ripening percentage, plant height and yield varied across weeding treatments.

DISCUSSION

Weeds are a major biological constraint to upland rice production, especially in low input systems, where resource constrained farmers cannot afford herbicides and therefore rely on manual labour for weed control (Becker and Johnson, 2001; Rodenburg and Johnson, 2009; Saito et al. 2010). In this study, the effect of weed management was investigated on the yield of the associated crop although it could have far reaching consequences on weed species composition and abundances. Effects of management variables on weed flora have been studied for annual crop production systems. Crop rotation and reduced tillage were found to be more important than the amounts of fertilizer and herbicide applied in restraining seed production for both grassy and broadleaf weeds (Kagode et al., 1999). In many parts of Uganda, weed management is not stringent, and is characterised with shallow tillage of weedy fields immediately before sowing, followed by occasional weed removal during the cropping season. As such, weed composition is more related to soil characteristics than cropping system (Ugen and Wortmann, 1997). Towards crop maturation, weeds are normally not removed and after crop harvest, weeds re-establish and continue to grow during the off season period resulting in a dynamic weed flora with an abundant supply of seeds and other propagules (Ugen and Wortmann, 1997).

This study investigated the effect of weeding regimes on selected agronomic traits in farmer preferred upland rice varieties. Generally, there was an increase in yield progressing from no weeding to first weeding, to second and third weeding, although the increases in yield varied with season and the trait considered. This observation agrees with that of Toure et al (2013) and JICA (2010) and confirms the benefit of weeding in rice production. Furthermore, traits such as number of panicle per metre squared, plant height and yield showed more variation compared others such as ripening percentage and 1000 grain weight. This observation corroborates that of Hogue et al (2013).

Given the fact that the small holder upland rice farmers rely on manual labour for weed control which also becomes scarce, it is important to consider the actual number of weeding regimes that would maintain a high rice yield. This study showed that there was almost no difference between the second and the third weeding regimes across the varieties and the traits measured. This observation agrees with that of Akobundu and Ahissou (1985), Alou et al. (2012) and Toure et al. (2011). Therefore, at least one well-timed weeding regime is sufficient to get a good rice yield under upland field conditions of Lake Albert crescent zone of Uganda.

At variety level, the observation of increase in rice yield at each weeding regime level was still evident. However, there was variation in varietal response to each weeding regime. This observation is similar that of several studies Fofana and Rauber (2000); Haefele et al., 2004; Rodenburg et al., 2009; Saito et al., 2010). Moreover, the variations observed across the range of varieties used in this study varied with each trait and season. Traits such as number of panicles per metre squared, ripening percentage, and yield showed the highest variation.

The interaction of weeding regime and variety

Table 5. Means for the effect of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2012 in the Lake Albert crescent zone of Uganda.

Weeding regime	Traits			
	Number of panicles/m^2	Number of spikelets per panicle	Ripening percentage	1000 grain weight (g)
No weeding	149a	32.8a	44.5a	28.2a
Weeding once	269^{b}	$47.4a^{b}$	12.7a	$24.4a^{b}$
Weeding twice	289^{b}	60.6^{bc}	12.5a	$19.9a^{b}$
Weeding thrice	310^{b}	66.7^{c}	22.2^{b}	23.7^{b}
Mean	254	52.0	23.0	24.1
LSD (0.05)	52.3	18.5	13.6	5.2
CV (%)	21.4	37.1	61.6	8.3

*Values within the column followed by the same letter are not significant at P<0.05.

Table 6. Means for the effect of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2013 in the Lake Albert crescent zone of Uganda.

Weeding regime	Traits				
	Number of panicles/m^2	Number of spikelets per panicle	Ripening percentage (%)	Plant height (cm)	Yield (kg/ha)
No weeding	112^{a}	56^{a}	37.5^{a}	78.4^{a}	714
Weeding once	310^{b}	91^{b}	72.0^{b}	95.3^{b}	5703
Weeding twice	264^{bc}	105^{b}	76.0^{b}	89.2^{bc}	5786
Weeding thrice	269^{c}	94^{b}	77.0^{b}	88.2^{c}	5593
Mean	239	87	65.6	87.8	4449
LSD (0.05)	44	14.8	8.5	6.4	1056
CV (%)	19.1	17.7	13.5	7.5	24.7

*Values within the column followed by the same letter are not significant at P<0.05.

Table 7. Means for the effect of weeding regime on the agronomic performance of farmer preferred upland rice germplasm for second season of 2014 in the Lake Albert crescent zone of Uganda.

Weeding regime	Traits				
	Number of panicles/m^2	Number of spikelets per panicle	Ripening percentage (%)	Plant height (cm)	Yield (kg/ha)
No weeding	111^{a}	56^{a}	37.5^{a}	66.9^{a}	71^{a}
Weeding once	306^{b}	88^{b}	74.6^{b}	86.1^{b}	570^{b}
Weeding twice	266^{b}	105^{bc}	76.1^{b}	86.9^{b}	598^{b}
Weeding thrice	266^{b}	95^{c}	76.9^{b}	85.5^{b}	559^{b}
Mean	237	86	66.3	81.4	449.5
LSD (0.05)	43.1	16.1	8.27	7.1	116.3
CV(%)	18.9	19.4	13.0	9.0	26.9

*Values within the column followed by the same letter are not significant at P<0.05.

Table 8. Heritability of three rice varieties grown in three trials across 4 weeding treatments.

Trait	Exp.1	Exp. 2	Exp. 3
1000 grain weight			
T1 = no weeding	0.82	0.95	0.95
T2 = Weeding once	0.83	0.99	1.00
T3 = Weeding twice	0.52	0.99	0.99
T4 = Weeding thrice	0.88	0.98	0.98
Number of panicles per m $^{-2}$			
T1 = no weeding	0.68	0.97	0.97
T2 = Weeding once	0.96	0.93	0.93
T3 = Weeding twice	0.87	0.97	0.93
T4 = Weeding thrice	0.82	0.97	0.97
Number of spikelets per panicle			
T1 = no weeding	0.18	0.77	0.77
T2 = Weeding once	0.88	0.66	0.73
T3 = Weeding twice	0.86	0.77	0.77
T4 = Weeding thrice	0.24	0.96	0.96
Ripening percentage			
T1 = no weeding	0.52	0.98	0.98
T2 = Weeding once	0.24	0.71	0.85
T3 = Weeding twice	0.24	0.95	0.95
T4 = Weeding thrice	0.67	0.93	0.93
Plant height (cm)			
T1 = no weeding	0.83	0.82	0.73
T2 = Weeding once	0.56	0.91	0.90
T3 = Weeding twice	0.09	0.82	0.44
T4 = Weeding thrice	0.78	0.68	0.91
Yield (kg/ha)			
T1 = no weeding	0.24	0.95	0.95
T2 = Weeding once	0.19	0.76	0.76
T3 = Weeding twice	0.16	0.61	0.64
T4 = Weeding thrice	0.69	0.94	0.94

Exp.1= Experiment 1; Exp. 2 = Experiment 2 and Exp.3 = Experiment 3; T1-T4 = treatments 1 to 4.

was not significant for most traits in all experiments, except traits such as ripening ratio and yield in experiment two and three. Yield is quantitative trait which is highly influenced by environment. In the context of our study, the different weeding regimes and seasons caused unique interactions with variety. Modal et al. (2013) observed a similar trend using three *Aus* rice varieties BR 26, BRRI dhan27, BRRI dhan48 and Pariza; and five weeding treatments viz. no weeding, one hand weeding at 20 DAS (Days after sowing), two hand weeding at 20 DAS and 30 DAS, three hand weeding at 20, 30 and 40 DAS and weed free condition planted using broadcasting method.

It should be noted that our results are unique to the population of upland rice varieties evaluated, and the rice production ecology (in this case, upland ecology). As such, they may not be applicable to other rice production ecologies or water stress conditions, and rice varieties. Therefore, validating our findings, including the identification of clear distinction between the effect of soil characteristics and management (weeding) might be needed before making recommendations based on them.

Conclusion

In conclusion, this study has found that there is a profound effect of weeding regime on upland rice yield in the study region. In addition, the study has also established that different varieties respond differently to the weeding regimes implemented by the farmer. Overall, the farmer may need to apply at least one hand hoe weeding activity on a highly responsive and well adapted variety, such as NERICA 4 to achieve an acceptable yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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