Growth and Yield Response of Upland Rice (*Oryza sativa* L.) to Different Nitrogen Fertilization and Weeding Levels

Emmanuel KOLO[1]
Joseph Aremu ADIGUN[2]
Olusegun Raphael ADEYEMI[2]
Olumide Samuel DARAMOLA[2] (✉)
Patience Mojibade OLORUNMAIYE[2]

Summary

Weed interference and poor soil fertility are important factors resulting in the poor yield of rice in Nigeria. A 2-year field study was therefore conducted to evaluate the effect of different nitrogen fertilization and weeding levels on growth and yield of upland rice in a forest savannah transition zone of Nigeria. A split-plot design in three replicates was used with three nitrogen fertilization levels (0, 60 and 90 kg ha^{-1}) as the main plot treatments, and four weeding levels (zero weeding, one hoe-weeding, two hoe-weedings and weed-free check) as the subplot treatments. Nitrogen fertilization levels had no significant effect on weed density, biomass and weed control efficacy. However, rice vigour, plant height, number of tillers and leaf area index increased significantly with increasing nitrogen fertilization levels up to 60 kg ha^{-1} and grain yield up to 90 kg ha^{-1}. Two hoe-weedings increased weed control efficacy similar to the weed-free check better than one hoe-weeding. Rice vigour, tiller number, leaf area index and grain yield increased as number of hoe-weeding also increased. Weed-free check that included four hoe-weedings was not better than two hoe-weedings carried out 3 and 6 weeks after sowing (WAS). The result of this study showed that nitrogen fertilization application at 90 kg ha^{-1} and two hoe-weedings at 3 and 6 WAS would improve weed control and productivity of upland rice.

Key words

grain yield, hoe-weeding, weed interference, weed control, rice competitive ability

[1] Department of Pest Management Technology, Niger State College of Agriculture, Mokwa, Niger State, Nigeria, PMB 109

[2] Department of Plant Physiology and Crop Production, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, PMB 2240

✉ Corresponding author: olumidedara01@gmail.com

Received: July 4, 2020 | Accepted: October 5, 2020

Introduction

Rice (*Oryza sativa* L.) is the most important staple food in Nigeria accounting for 10.5% of the average caloric intake (Durand-Morat et al., 2019) and 6% of household expenses (Johnson et al., 2013). Rice is the most rapidly expanding food commodity both in term of consumption and production, and therefore a central crop for food security and income generation for farmers in Nigeria (Durand-Morat et al., 2019). However, its consumption rate exceeds its present level of production, making Nigeria the second largest importer of rice after China with an average of 2.4 million metric tons a year (Durand-Morat et al., 2019; USDA-ERS, 2019). It is largely grown by smallholder farmers in farms usually less than a hectare under upland conditions (Takeshima and Bakare, 2016). This situation has been attributed to the low productivity and poor yield obtained from farmers' field in Nigeria (Johnson and Ajibola, 2016). Average rice yield in Nigeria (2.0 t ha^{-1}) is only about half of the global average yield (5.4 t ha^{-1}) and far below Egypt's 9.5 tha^{-1} (Durand-Morat et al., 2019).

Weed interference is one of the principal factors responsible for the poor yield of rice in Nigeria and other parts of Africa (Waddington et al., 2010: Adigun et al., 2017) since at the beginning of its vegetation rice is a weak competitor against weeds. Moreover, rice is sown at close spacing of 50 cm or below, which makes mechanical weed control difficult, resulting in high yield losses up to 90% (Adeyemi et al., 2017; Adigun et al., 2017). In Africa, yield losses due to weed interference are estimated to be at least 2.2 million tons per year, valued at $ 1.5 billion (Rodenburg and Johnson 2009). Weed control method currently employed by smallholder farmers to reduce such losses is predominantly manual hoe-weeding. Although hoe-weeding is very important when trying to avoid the development of potential serious weed problems, labour shortage and its attendant cost is a major constraint (Datta et al., 2017; Adigun et al., 2017). On the other hand, currently available rice herbicides do not control the entire weed spectrum with diverse physiology, morphology and time of emergence (Khaliq et al., 2014), and their efficacy is further limited under conditions of high rainfall and prolonged weed germination period (Mahajan and Timsina, 2011; Daramola et al., 2020). Moreover, smallholder farmers lack the technical know-how for correct herbicide application. Phytotoxicity and environmental problems that might be induced when herbicides are wrongly applied have made the use of post-emergence herbicides less desirable for smallholder farmers (Labrada, 2003; Khaliq et al., 2014).

The adoption and execution of weed management approach that would decrease farmers' reliance on herbicides and multiple hoe-weeding have been advocated to adequately address the problem posed by weeds in rice production (Maity and Mukherjee, 2008; Adigun et al., 2017). Enhancing the competitive ability of rice against weeds is an important means of achieving that goal. The competitive relationship between rice and weeds is highly dependent on many factors including the supply and availability of nutrients (Blackshaw et al., 2005; Mahajan and Timsina, 2011). Of all nutrients, plant response to nitrogen fertilizer is most widely observed (Camara et al., 2003). Adequate nitrogen fertilizer application has a potential to produce a vigorous rice crop with enhanced competitiveness against weeds whereas excessive application could lead to luxuriant weed growth (Mahajan and Timsina, 2011). There is, therefore, need to systematically integrate this weed management strategy into the production practice of smallholder farmers to combat weed problem in a sustainable manner within the context of integrated weed management. Since manual weed control is a major aspect of rice production in Nigeria, the future expansion of area under rice cultivation is contingent upon appropriate cultural practices such as nitrogen application that would enhance crop competitiveness against weeds and consequently reduce weeding burden. Hence, the aim of this study was to evaluate the performance of upland rice under different nitrogen fertilization and weeding levels.

Materials and Methods

Field experiments were conducted during the cropping seasons of 2014 and 2015 at the Research Farm, Federal University of Agriculture, Abeokuta (7°15' N; 3°25' E) in the transition zone of Nigeria. The soil was a sandy loam Oxic Paleudulf with 6.7 and 6.9% organic matter, 0.16 and 0.18 cmol kg^{-1} total nitrogen, 1.1 and 1.3 cmol kg^{-1} available phosphorus, 1.3 and 1.5, cmol kg^{-1} potassium, 0.4 and 0.6 cmol kg^{-1} calcium and 7.12 and 7.23 cmol kg^{-1} of magnesium with pH of 6.7 and 6.9 in 2014 and 2015, respectively in the top 20 cm. The experimental site was previously fallow for 1 year after cropping with peanut (*Arachis hypogea* L.) and cowpea (*Vigna unguiculata* L.) for the previous 2 years. Meteorological data during the period of crop growth in both years are presented in Table 1. The major weed species at the site were *Euphorbia heterophylla* (Linn.), *Gomphrena celosioides* (Mart.), *Boerhavia diffusa* (Linn.), *Chromolaena odorata* (L.) R. M. *King and Robinson*, and *Digitaria horizontalis* (Willd.) before the study started. The site was cleared manually and ploughing and harrowing were done mechanically at a two-week interval.

A split-plot design was used with three nitrogen fertilizer application levels (0, 60 and 90 kg ha^{-1}) as the main plot treatments, and four weeding levels (zero weeding, one hoe-weeding at 3 weeks after sowing (WAS), two hoe-weedings at 3 and 6 WAS, and the weed-free check that included four hoe-weddings at 3, 6, 9 and 12 WAS) as the subplot treatments in randomized complete blocks with three replicates. Each subplot was 13.5 m^2 in size. Rice seeds (var. NERICA 2) were sown by drilling method at inter-row spacing of 50 cm in both years. Nitrogen fertilizer was applied as urea in two equal splits by drilling into furrows 10 cm from the plants at 3 and 6 WAS in both years.

Data on weed density and biomass were taken at 9 WAS from a 50 cm^2 quadrat randomly placed at three spots within each plot. Weeds sampled from the quadrat were counted, oven-dried at 70°C until constant weight, and dry biomass was recorded. Weed control efficacy (%) of each treatment was evaluated by visual rating at 9 WAS based on a scale of 0 to 100% where 0 represents plots fully covered with weeds (no weed control) and 100 represents plots with no weed cover (complete weed control) (Hajebi et al., 2016). Data on rice were collected from 10 tagged plants within the net plots at 9 WAS to determine crop vigour score, plant height (cm $plant^{-1}$), number of tillers (number m^{-1}) and leaf area index. Crop vigour score was accessed by visual estimate based on scale 0-10, where 0 represents completely dead plant and 10 represents the most vigorous plant (Tunku et al., 2007; Adigun et al., 2017). The leaf area index (LAI) was calculated following the formula of Watson (1947).

Table 1. Total rainfall, mean temperature and relative humidity during the period of crop growth in 2014 and 2015

Month	Total rainfall (mm)		Mean temperature (° C)		Relative humidity (%)	
	2014	2015	2014	2015	2014	2015
June	53.7	53.7	27.0	26.8	71.0	70.8
July	202.0	202.6	25.5	27.2	76.2	73.0
August	35.2	35.2	24.3	26.2	71.6	70.3
September	135.6	136.0	25.6	26.3	70.0	71.9
October	94.7	94.4	27.0	26.3	67.2	67.2
Total	522	584				

Rice was harvested manually and grain yield from each plot was recorded at 14% moisture content and expressed in t ha^{-1}. During harvesting, 10 hills were selected within the net plot for measuring panicle length (cm), panicle weight (g) and number of grains per panicle. Data were subjected to analysis of variance using GENSTAT (18th edition, Rothamstead Experimental Station, Hertfordshire, UK). Replicate effects were considered random, while treatment effects were considered fixed. The means were separated using 5% least significant difference (LSD ≤0.05).

Results and Discussion

Weed Species Composition

Twenty weed species were recorded during the period of crop growth in 2014 and 2015. The weed species comprised of ten broadleaf weeds, eight grasses, and two sedges (Table 2). The most dominant weed species averaged across the treatments in both years were *E. heterophylla, Tridax procumbens* (Linn.), *G. celosioides, Commelina benghalensis* (Burn.), and *D. horizontalis* (Table 2). The prevalence of both annual and perennial broadleaved weeds and grasses in this study may be a result of high disturbance environment that favour them (Menalled et al., 2001). However, there were differences in the level of weed infestation between the two years. The weed species were generally less abundant in 2014 than in 2015. Some of the weed species such as *Commelina benghalensis, Gomphrena celosioides, Boerhavia diffusa, Talinum triagulare, Chromolaena odorata* and *Digitaria horizontalis* with moderate infestation in 2014 were found with high infestation in 2015 (Table 2). The variability in the level of weed infestation between two years may be attributed to rainfall differences. The rainfall was generally more abundant and evenly distributed in 2015 than in 2014. It has been reported that rainfall affects weed species distribution and their competitiveness within a crop community (Shahidul et al., 2011).

Effect of Different Nitrogen Fertilization and Weeding Levels on Weed Density and Biomass and Weed Control Efficacy

Weed density, biomass as well as weed control did not differ significantly between different nitrogen fertilizer levels in both years. Average values for weed density, biomass and weed control efficacy across the nitrogen fertilizer levels were 18.6, 40.8 and 57.5, respectively in 2014 and 23.8, 40.6 and 57.1, respectively in 2015. This was probably due to the timing and method of application which made the fertilizer available to the rice plants and not to the weeds. The two splits of nitrogen application were done in the third and sixth weeks of crop growth immediately after weed control by hoe-weeding. Hence, the nitrogen applied did not stimulate weed growth, but rather enhanced rice growth. The banding method of application used in this study decreased fertilizer availability to weeds and did not encourage weed growth between the crop rows, but placed the fertilizer where the crop could reach it quickly as suggested in Fanadzo et al. (2010). Our result supports the previous findings of Adigun et al. (2017), who reported that nitrogen fertilizer application had no effect on weed growth when banding method of application was used in a study conducted in the forest savannah transition zone of Nigeria. This absence of a response to nitrogen application is somewhat contrary to previous report of Mahajan and Timsina (2011) who observed an increase in weed density and biomass with increasing nitrogen rates in rice using banding method of application in a study conducted in India where the main infesting weed species were *Echinochloa colona, E. crussgali* and *Digitaria sanguinalis*. Such differences in the effect of nitrogen application on weed growth in the present study may be attributed to differences in infesting weed species. Andreason et al. (2006) and Kim et al. (2006) earlier reported that weed growth could be increased, unchanged, or reduced with increasing nitrogen application, depending on the infesting weed species. This indicates that weed response to nitrogen application is species dependent.

Conversely, weed density and biomass and weed control efficacy differed significantly between weeding levels in both years (Table 3). Weed density was the lowest in plots weeded twice, compared to plots weeded once or kept weedy. With one hoe-weeding weed density was reduced by 41 - 61% and with two hoe-weedings by 71 -78% in both years, respectively (Table 3). The lowest weed biomass was recorded in plots weeded twice, compared to plots weeded once or kept weedy. Consequently, weed control efficacy increased as the number of hoe-weeding increased. However, weed control efficacy obtained in the weed-free check (100%) was not significantly better than that of two hoe-weedings (86.5 - 89.6%) in both years, indicating that efficient weed control in rice can be achieved with two hoe-weedings carried out in the third and sixth weeks after sowing. Weeds coming later in the growing season are less aggressive due to more developed rice canopy and therefore lower weeds growth rate.

Table 2. Weed species and level of infestation during the experiment in 2014 and 2015

Weed species	Life cycle	2014		2015	
		Plants m^{-2}	Level of infestation	Plants m^{-2}	Level of infestation
Amaranthus spinosus Linn.	Annual broad leaf	20.9	LIa	29.7	MI
Boerhavia diffusa Linn.	Perennial broad leaf	25.8	LI	44.5	MI
Commelina benghalensis Burn.	Perennial broad leaf	45.6	MI	68.8	HI
Euphorbia heterophylla Linn.	Annual broad leaf	57.8	MI	76.8	HI
Gomphrena celosioides Mart.	Annual broad leaf	54.5	MI	66.3	HI
Spigelia anthelmia Linn.	Annual broad leaf	23.8	LI	33.6	MI
Tridax procumbens Linn.	Annual broad leaf	58.9	MI	75.7	HI
Chromolaena odorata (L.) R.M. King and Robinson	Perennial broad leaf	36.7	MI	38.9	MI
Talinum triangulare (Jacq.) Willd.	Perennial broad leaf	34.7	MI	39.8	MI
Trianthema portulacastrum Linn.	Perennial broad leaf	24.4	LI	27.8	LI
Digitaria horizontalis Willd.	Annual grass	50.7	MI	77.7	MI
Panicum maximum Jacq.	Perennial grass	44.6	MI	46.8	MI
Axonopus compressus (Sw.) P. Beauv	Perennial grass	32.5	MI	34.7	MI
Eleusine indica Gaertn.	Annual grass	35.7	MI	40.8	MI
Rottboellia cochinchinensis (Lour.) Clayton	Annual grass	23.6	LI	25.0	LI
Cynodon dactylon (L.) Gaertn	Perennial grass	32.8	MI	40.0	MI
Paspalum scrobiculatum (Linn.)	Perennial grass	30.7	MI	33.6	MI
Brachiaria deflexa (Schumach.) C.E. Hubbard	Perennial grass	22.7	LI	26.7	LI
Cyperus rotundus Linn.	Perennial sedge	30.7	MI	33.3	MI
Cyperus esculentus Linn.	Perennial sedge	34.2	MI	35.3	MI

Note: [a]LI= Low infestation 1-29 plants m^{-2}; MI = Moderate infestation 30-59 plants m^{-2}; HI =High infestation 60-90 plants m^{-2}

Table 3. Effect of weeding levels on weed density, biomass, and weed control efficacy in 2014 and 2015

Weeding levels	Weed density plants (m^{-2})		Weed biomass (g m^{-2})		Weed control efficacy (%)	
	2014	2015	2014	2015	2014	2015
Zero weeding	46.3a[#]	50.9a	61.9a	62.6a	0.0d	0.0d
One hoe-weeding	17.8b	29.6b	56.3b	57.2b	42.2c	44.6c
Two hoe-weeding	10.4c	15.2c	41.7c	42.8c	89.6b	86.5b
Weed-free check	-	-	-	-	100.0a	100.0a
LSD (P≤0.05)	5.8	7.8	8.1	8.8	19.2	20.1

Note: [#]Means followed by same letters are not significantly different according to the LSD test (P ≤ 0.05)

It means that, additional weeding after 6 weeks of crop growth is considered superfluous, and may reduce weed species diversity, and increase both soil erosion and cost of manual labor, which represent the bulk of production cost (Adigun and Lagoke, 2003; Ovalle et al., 2007). Our result supports the finding of Ekeleme et al. (2009) and Khaliq et al. (2014) who reported that rice was less vulnerable to weed competition during its late phases of growth, and therefore required weed removal only within the first 6 weeks of crop growth for efficient weed control.

Effect of Different Nitrogen Fertilization and Weeding Levels on Growth and Yield of Rice

The effect of different nitrogen fertilizer application levels was significant for rice vigour score, plant height, number of tillers, leaf area index and grain yield, but not for number of grains per panicle, panicle length and panicle weight in both years (Table 4). The application of nitrogen fertilizer at 60 kg ha^{-1} resulted in significant increase in rice vigour, plant height, number of tillers and leaf area index compared with zero nitrogen fertilizer application in both years. However, an increase in nitrogen fertilizer application from 60 to 90 kg ha^{-1} did not cause any significant increase in these growth parameters in both years (Table 4). Similarly, rice grain yield increased significantly with increased nitrogen fertilizer application levels from 0 to 90 kg ha^{-1} in both years (Table 4). Rice grain yield obtained with 90 kg nitrogen fertilizer ha^{-1} was 27 - 50% higher than grain yield obtained with 60 kg nitrogen fertilizer ha^{-1} and obtained with zero nitrogen fertilizer application in both years. Similarly, 60 kg nitrogen fertilizer ha^{-1} increased rice grain yield by 10 - 13% compared with zero nitrogen fertilizer application in both years (Table 4). The lowest growth and grain yield obtained with zero nitrogen fertilizer application treatment justifies the need of nitrogen fertilizer for improved rice growth and yield in tropical soils, as earlier reported by Adigun et al. (2017). The improvement in vegetative growth observed with nitrogen fertilizer application is attributable to the effect of applied nitrogen in chlorophyll formation which allows plants to convert solar energy to sugar used for growth (Brady and Weil, 2002), thus plants become more vigorous, taller, and with more tillers and higher leaf area index as a result of production of more photosynthates. The increase in rice grain yield with increasing nitrogen fertilizer application up to 90 kg ha^{-1} was probably due to better and early canopy formation which reduced weed seed germination and weed completion for growth resources (Jovicich et al., 2003).

Weeding levels influenced rice growth and yield significantly in 2014 and 2015 (Table 4). As expected, all weeding levels increased rice growth and yield significantly compared with zero weeded plot in both years. The lower growth and yield in zero-weeded plots showed that weeds caused significant growth and yield reduction in rice as earlier reported by Mahajan and Timsina (2011) and Khaliq et al. (2014). Plots hoe-weeded once or twice, and weed-free check recorded similar rice plant height and panicle length in both years (Table 4). One and two hoe-weedings resulted in similar number of rice grains per panicle and panicle weight in both years (Table 4). The highest number of grain per panicle and panicle weight was recorded in the weed-free check in both years (Table 4).

Table 4. Effect of nitrogen fertilizer and weeding levels on rice growth parameters, rice grain yield and yield attributes in 2014 and 2015

	Crop vigour score[a]		Plant height (cm)		Number of tillers		Leaf area index		Number of grains		Panicle length (cm)		Panicle weight (g)		Grain yield (t ha^{-1})	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Nitrogen levels																
0	4.1a[#]	4.7a	81.6b	80.2b	29.7b	36.1b	1.18c	1.00c	139.2	137.1	21.2	21.3	36.2	37.8	2.3c	2.0c
60	5.0b	9.6b	95.2a	96.2a	58.6a	56.7a	1.52a	1.27a	148.0	132.6	20.8	20.3	36.2	36.8	2.6b	2.2b
90	5.5b	9.7b	96.7a	99.0a	67.8a	59.4a	1.75a	1.47a	156.3	145.9	22.5	21.1	41.6	39.9	3.3a	3.0a
LSD ($P \leq 0.05$)	0.6	0.3	2.98	4.8	9.48	5.3	0.25	0.20	1.9ns	10.0ns	0.8ns	0.8ns	4.4ns	3.1ns	0.2	0.1
Weeding levels																
Zero weeding	2.7c	6.3c	51.7b	51.5b	42.2c	15.9c	0.77c	0.77c	97.2c	71.9c	17.9b	14.5b	29.4c	20.9c	1.72c	1.10c
One hoe-weeding	4.0b	7.2b	105.6a	104.4a	50.4b	55.0b	1.65b	1.36b	150.7b	142.4b	21.7a	22.1a	37.7b	41.4b	2.44b	2.26b
Two hoe-weeding	6.1a	9.1a	104.3a	104.9a	57.4a	65.0a	1.75a	1.40a	152.8b	153.3b	22.4a	22.5a	37.3b	40.3b	3.23a	3.01a
Weed-free check	6.7a	9.3a	103.0a	106.4a	58.1a	66.4a	1.76a	1.44a	190.6a	186.5a	23.9a	24.5a	47.6a	50.0a	3.60a	3.34a
LSD ($P \leq 0.05$)	0.6	0.4	3.45	5.5	5.17	6.1	0.08	0.03	19.5	11.5	2.4	2.9	5.1	3.5	0.4	0.36

Note: [a]Crop vigour score was accessed by visual estimate based on scale 0-10: where 0 represents completely dead plant and 10 represents most vigorous plant. [#]Means followed by same letters are not significantly different according to the LSD test ($P \leq 0.05$)

Rice vigour score, number of tillers, leaf area index and grain yield increased as the number of hoe-weeding increased, but the weed-free check that included four hoe-weedings was not better than two hoe-weeding in increasing these growth parameters and rice grain yield in both years (Tables 4). This was probably because two hoe-weedings and the weed-free check had similar weed control efficacy in both years. This result showed that hoe-weeding twice, in the third and the sixth weeks after sowing was adequate for optimum grain yield of rice. With the advent of increase cost of labor for hoe-weeding, two hoe-weedings will be advantageous because of the possibility of reducing cost of weed control. This result is in agreement with the report of Adeyemi et al. (2017) who reported optimum rice yield with two hoe-weedings in lowland rice.

Conclusion

This study demonstrated that effectiveness of nitrogen application at 90 kg ha^{-1} and two hoe-weedings carried out twice after sowing for efficient weed control and optimum yield of rice. Nitrogen application enhanced early rice growth and provided a competitive advantage for the crop against infesting weed species, particularly at the later stage of crop growth. The efficacy of two hoe-weedings in this study was similar to that of the weed-free check that included four hoe-weedings. Farmers can therefore reduce labor cost for multiple hoe-weedings with the application of nitrogen at 90 kg ha^{-1} and two hoe-weedings in the third and sixth weeks after sowing in rice cultivation.

References

Adeyemi O. R., Adigun, J. A., Hosu, D. O., Fanawopo, H. O., Daramola, O. S., Osipitan A. O. (2017). Growth and Yield Response of Two Lowland Rice Varieties (NERICA L-19 and WITA 4) as Influenced by Period of Weed Interference in the Forest Savannah Agroecological Zone of Southwest Nigeria. Nigerian J Eco 16 (2): 142-160

Adigun J. A., Kolo E., Adeyemi O. R., Daramola O. S., Badmus O. A. (2017). Growth and Yield Response of Rice to Nitrogen Level and Weed Control Methods Inter J Agro and Agric Res11 (6): 92-101

Adigun J. A., Lagoke S.T.O. (2003). Weed Control in Transplanted Rain and Irrigated Tomatoes in the Nigerian Savannah. Nigerian J Weed Sci 16: 23-29

Andreason C., Slitz C. A., Striebig C. (2006). Growth Response of Six Weed Species and Spring Barley to Increasing Levels of Nitrogen and Phosphorus. Weed Res 46: 503–512

Blackshaw R. E., Molnar L. J., Larney F. J. (2005). Fertilizer, Manure and Compost Effects on Weed Growth and Competition with Winter Wheat in Western Canada. Crop Prot 24: 971–980

Brady N. C., Weil R. R. (2002). The Nature and Properties of Soil. 13th Edition. Pearson Education Publication, New Delhi, India. pp. 881-889

Camara K. M., Payne W. A., Rasmussen P. E. (2003). Long-Term Effects of Tillage, Nitrogen and Rainfall on Winter Maize Yields in the Pacific Northwest. Agro J 95: 828–835

Daramola O. S., Adeyemi O. R., Adigun J. A., Adejuyigbe C. O. (2020). Weed Interference and Control as Affected by Row Spacing in the Transition Zone of South West Nigeria. J crop Improv 34 (1): 103-121

Datta A., Ullah H., Tursun N., Pornprom T., Knezevic S.Z., Chauhan B. S. (2017). Managing Weeds Using Crop Competition in Soybean (*Glycine max* (L.) Merr.) Crop Prot 95: 60-68

Durand-Morat A., Chavez E., Wailes E. (2019). International Rice Outlook, International Baseline Projections, 2018-2028. International Rice Outlook.

Ekeleme F., Kamara A. Y., Oikeh S. O., Omoigui L. O., Amaza P., Abdoulaye T., ChikoyeD. (2009): Response of Upland Rice Cultivars to Weed Competition in the Savannas of West Africa. Crop Prot 28 (1): 90–96

Fanadzo M., Chiduza C., Mnken P. N. S. (2010). Pre-Plant Weed Control, Optimum N Rate and Plant Densities Increase Butternut (*Cucurbita moschata*) Yield under Smallholder Irrigated Conditions in the Eastern Cape Province of South Africa. African J. Agric Res 5 (16): 2192-2199

Food and Agriculture Organization (FAO), 2019. FAOSTAT. http://www.fao.org/faostat/en/#home [Accessed 9 April 2019].

Hajebi T. K., Dasa-Arorab A., Singh S. B., Hajebi F. (2016). Herbicides Tank-Mixes Effects on Weeds and Productivity and Profitability of Chilli (*Capsicum annuum* L.) under Conventional and Zero Tillage. Scientia Hort 198: 191-196

Johnson M., Ajibola A. (2016). Post-Harvest Processing, Marketing and Competitiveness of Domestic Rice. In: Gyimah-Brempong, K., Johnson, M., Takeshima, H., Gyimah- Brempong, K., Johnson, M., Takeshima, H. (Eds.), The Nigerian Rice Economy: Policy Options for Transforming Production, Marketing and Trade. University of Pennsylvania Press, Philadelphia.

Johnson M., Takeshima H., Gyimah-Brempong K., Kuku-Shittu O., Diao X., Dorosh P., Malek M., Koo J., Pradesha A., Ajibola A. (2013). Policy Options for Accelerated Growth and Competitiveness of the Domestic Rice Economy in Nigeria. International Food Policy Research Institute, Washington DC.

Jovicich E. D., Cantiffe J., Stoffella P. J., Vansickle J. J. (2003). Reduced Fertigation of Soil-Less Greenhouse Peppers Improves Fruit Yield and Quality. Acta Hort 609: 193-199

Khaliq A., Matloob A., Ahmed Chauhan B.S. (2014). Weed Management in Direct Seeded Rice under Varying Row Spacing in the Rice-Wheat System of Punjab, Pakistan. Plant Prod Sci 17(4): 321-332

Kim D. S., Marshall J., Caseley C., Brain P. (2006). Modeling Interactive between Herbicide and Nitrogen Fertilizer in Terms of Weed Response. Weed Res 46: 480–491

Labrada R. (2003). The Need for Improved Weed Management in Rice. Sustainable Rice Production for Food Security". Proceedings from the 20th Session of the International Rice Commission. 23-25th July 2002, Bangkok, Thailand.

Mahajan G., Timsina J. (2011). Effect of Nitrogen Rates and Weed Control Methods on Weeds Abundance and Yield of Direct Seeded Rice. Archives Agro and Soil Sci, 57(3): 239-250

Maity S. K., Mukherjee P. K. (2008). Integrated Weed Management in Dry Direct Seeded Rainy Season Rice. Indian J Agro 53: 116-120

Menalled F. D., Gross K. L., Hammond M. (2001). Weed Aboveground and Seed Bank Community Responses to Agricultural Management Systems. Eco App 11: 1586–1601

Ovalle, C.M., Carlos, M., Gonzalez Maria Ines, A., Del Pozo, A.L., Hirzel, J.C., Hernaiz, V., 2007. Cubiertas vegetales en producción orgánica de frambuesa: Efectos sobre el contenido de nutrientes del suelo y en el crecimiento y producción de las plantas. Agrictéc 67: 271-280

Rodenburg J., Johnson D. E. (2009). Weed Management in Rice-Based Cropping Systems in Africa. Advances Agro 103: 149–218

Shahidul H. B., Min Y. E, Romij M. D, Tea S. P, Hang W. K, Do S. K, Park K. W. (2011). Weed Population Dynamics under Climatic Change. Asian J Turf Grass Sci 25 (1): 174-182

Takeshima H., Bakare O. (2016). Production Systems: Biophysical and Economic Environment and Constraints. In: Gyimah-Brempong, K., Johnson M., Takeshima H. (Eds.), The Nigerian Rice Economy; Policy Options for Transforming Production, Marketing and Trade. University of Pennsylvania Press, Philadelphia, Pennsylvania, pp. 51–84

Tunku, P., Lagoke S. T. O., Ishaya, D. B. (2007). Evaluation of Herbicides for Weed Control in Irrigated Garlic (Allium sativum L.) at Samaru, Nigeria. Crop Protection 26, 642-646

United States Department of Agriculture, Economic Research Service (USDA - ERS), (2019). International Baseline Data: 2019 International Long-Term Projections to 2028. https://www.ers.usda.gov/data-products/international-baseline-data/ [Accessed 15 November 2019]

Waddington S. R., Li X. Y., Dixon J., Hyman G., De-Vicente M. C. (2010). Getting the Focus Right: Production Constraints for Six Major Food Crops in Asian and African Farming Systems. Food Sec 2: 27–48

Watson D. J. (1947). Comparative Physiological Studies in the Growth of Field Crops. I. Variation in Net Assimilation Rate and Leaf Area between Species and Varieties, and within and between Years. Annals Bot 11: 41-76

aCS86_13