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Predicting Critical Period of Weed Control for Optimum Yield of Upland Rice (*Oryza sativa* L.) in the Sudan savanna of Nigeria

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Abstract: *Critical period of weed interference studies are indispensable in making weed control recommendations, as they indicates optimum time for implementing weed management. The experiments were conducted in 2016 raining seasons concurrently at Bayero University Kano (11^0 39'N;08"02E) and Audu Bako College of Agriculture Dambatta ($12^0$10' N, $8^0$39' E) Teaching and Research Farms both in Kano State within the Sudan savanna agro-ecological zone of Nigeria. The aim of the experiments were to determine the critical period of weed control and estimate the number of days that the crop should be kept weeds free inorder to attain a predetermined level of allowable yield loss in upland rice production. Weed competition either before or after these critical periods had negligible effects on the crop yield. The experiment comprises two sets of weed removal process, the first is weed free periods, where plots were maintained weed free until 14, 28, 42, 56 days after emergence (DAE) and until harvest, while the second set i.e weed infested periods, the weeds were allowed to compete with rice crop right from their emergence until 14, 28, 42, 56 DAE and until harvest. The experiments were laid out by in a Randomized Complete Block Design and replicated four times. The result indicated rice grain yield decrease with prolonged delays in weed removal; conversely, grain yield increase with the increasing length of weed-free period in both locations. The result indicated that under the similar experimental conditions, direct seeded rice field could be kept weed-free during 10 – 66 DAE to achieve 95% of weed-free yield, and 16 – 60 DAE to achieve 90% of weed-free yield, and also 21 – 54 DAE to achieve 85% of weed free yield at the study area.*

Key words: *Critical, Emergence, Interference, Weed*

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I. Background Information

Rice (*Oryza sativa* L.) is a principal source of food for more than half of the world's population, especially in South and Southeast Asia, Latin America and Africa (Rao *et al.*, 2007). In Nigeria rice is a staple food and consumed by individuals across all levels of incomes. Global land area for paddy plantings in 2017 was estimated at 163.8 million hectares, yields remained close to that of 2015 at an average of 4.6 tonnes per hectare and the total world production in 2017 was 756.7 million tonnes (FAO, 2017). Nigeria is the second largest producer of rice in Africa with a total of 5.4 million tonnes of paddy rice in 2017 (FAO, 2017). But still Nigeria spent the sum of $2 billion USD on rice importation (CBN newsletter, 2015). Nigeria has the potential to be self-sufficient in rice production, both for food and industrial raw material needs and for export. However, a number of constraints have been identified as limiting to rice production efforts by farmers. Ukungwu and Abo (2004) reported that weed is the greatest bottleneck to increased yields and quality of rice in Nigeria, particularly in the upland ecology and ranks only second to drought stress.

Critical period studies are indispensable in making weed control recommendations, as they indicate optimum time for implementing and maintaining weed control (Van-Acker *et al*., 1993). Productivity of direct-seeded rice is believed to largely depend on effective and timely weed control. Zimdahl (1988) identified the period during which weeds must be controlled to prevent economic yield loss. This, in turn requires knowledge about critical period of weed competition. Information on the critical period of weed competition in direct-seeded rice could help improve timing of post emergence herbicides application. In order to provide more precise information for growers, CPWC should be determined specifically for a particular region by considering the weed composition and climatic conditions (Knezevic *et al*., 2002). The objectives of this work is to to determine the critical period of weed interference in upland rice production system in Kano state Sudan savanna of Nigeria

II. Experimental Sites

The experiment was conducted in 2016 raining season at two locations concurrently i.e. Bayero University Kano (BUK) Teaching and Research Farm (11^0 39'N;08"02E) in Ungogo Local government Area and Audu Bako College of Agriculture Research Farm Thomas Dambatta **(**$12^0$10' N, $8^0$39' E;) in Makoda Local Government Area both in Kano State within the Sudan savanna agro-ecological zone of Nigeria.

III. Weather And Soil Characteristic of the Experimental Sites

The total amount of rainfall received was 863 mm and 934 mm for BUK and DBT sites respectively, in 2016. It indicated moderate rainfall, though rainfall recorded at DBT was slightly higher than in its BUK counterpart in that year but distribution was not even. The minimum and maximum temperature was very high at the beginning of the raining seasons at both locations. The temperature had however, gradually decreased as the amount of rainfall was increasing upto the month of August where it spontaneously increased as a result of decreased volume of rainfall received toward the end of theraining season.

The soil was sandy loam and loamy sand for BUK and DBT, respectively. The soil pH was slightly acidic to neutral. Total nitrogen content was generally low; very low organic carbon and high available P was also observed at both locations. It also indicated moderate potassium and calcium content and low cation exchange capacity (CEC).

IV. Treatments And Experimental Design

This comprised of two sets of weed removal treatments. The first consisted of weed free periods were plots were maintained weed free until 14, 28, 42, 56 days after emergence (DAE) and until harvest. The second set namely weed infested periods, where weeds were allowed to compete with rice crop right from their emergence until 14, 28, 42, 56 DAE and until harvest. Control plots were kept weed free or weed infested throughout the growth period. The weeds were removed by hand pulling and hoeing. The experiment was laid out using randomized complete block design and replicated four times.

V. Rice Variety Used For The Experiment

The rice variety used for the trial is NERICA 8 (FARO 59). It is a hybrid between *Oryza sativ*a and O*ryza glabberima* developed by WARDA in 1994. The variety is an upland type, medium height, it has 50% days to heading of 55 - 60 days, it matures in 80 -90 days, it has long grain and potential yield of 5 t ha^{-1}. It is resistant to leaf blast disease and lodging. (Gridley *et al.*, 2002)

VI. Data Collection

Weed species composition

Weeds were harvested from the $1m^2$ quadrant placed randomly in each net plot at harvest. The harvested weed samples were identified and classified by species with the help of a Hand Book of West African Weeds by Akobundu and Agyakwa (1998)

Paddy yield (kg ha^{-1})

The paddy yield was measured after threshing the sun-dried plants harvested from each net plot and the yield was adjusted at 10 % seed moisture content.

DATA ANALYSIS

Data generated were subjected to analysis of variance as described by Snedecor and Cochran (1967) using the general linear model in SAS (SAS, 2004). Where significant, the treatments means were separated by using Duncan multiple range test (DMRT).

Determination for Critical Weed Interference Period

The critical time of weed removal and the critical weed free period was calculated by substituting rice yields, expressed as percentage of weed free control into Gompertz and Logistic equations (Gompertz and Rawlings, 1992). Allowable yield loss (AYL) levels of 5%, 10% and 15% were chosen arbitrarily. The equation with the highest coefficient of determination (R^2) value was judged to be the most appropriate. The equations were fit using the nonlinear regression techniques as described by Hall *et al.* (1992). The maximum rice yield loss due to weed interference was calculated by the use of the following formulae:

$$1 - \left(\frac{\text{Rice yield in weedy check}}{\text{Rice yield in weed free check}}\right) X \ 100$$

VII. Results And Discussion

Weed species composition

Weed species composition of the experimental sites is presented in Table 1. There were a total of eighteen (18) weed species identified at BUK, seven were grasses, five were broad leaved and six were sedges. *Roattboellia cochichinensis* had the highest relative frequency 0f 18.5% which was followed by *Ipomea asarifolia* (13.1%) while the least relative frequency was recorded by *Oryza longistaminata* (1.5%). There were a total of fifteen (15) weed species identified at DBT, seven were broad leaved; grasses and sedges were four each. *Fimbristylis ferruginea* had the highest relative frequency 0f 8.5% while the least figure was recorded by *Oryza longistaminata* (2.5%).

Weed Species Composition of BUK and DBT in 2016 raining Season

Weed species	Common name	Relative frequency (%)	
		BUK	DBT
Grasses			
Rottboellia cochinchinensis	Itch grass	18.5	-
Imperata cylindrical	Spear grass	3.0	-
Panicum maximum	Guinea grass	2.0	7.4
Digitaria horizontalis	Crab grass	3.0	7.7
Cynodon dactylon	Bahama grass	8.1	8.1
Eluecine indica	Goose grass	2.0	6.4
Broad leaved			
Ipomea asarifolia	water spinach	13.1	7.2
Seena occidentalis	Coffee senna	5.0	8.3
Amaranthus spinosus	spiny amaranth	4.0	5.5
Acathusparnum hispidum	Star burr grass	-	8.3
Tridex procumbens	coat buttons	14.1	6.9
Phyllanthus amarus	____	9.1	6.8
Commelina benghalensis	Tropical spiderwort	2.0	-
Sedges			
Leersia hexandra	Cut grass	2.0	-
Cyperus esculantus	Yellow nut sedge	7.3	7.9
Kylingya squamulata	____	3.0	7.2
Fimbristylis ferruginea	____	3.0	8.5
Oryza longistaminata	Wild rice	1.2	2.1
Achyranthes aspera	devil's horsewhip	1.5	-

Effect of weed interference on paddy yield and critical period of weed control

Significant differences (P > 0.05) on paddy yield were recorded at both locations (Table 1). The Significantly higher paddy yield was recorded by the WF until harvest at all the locations. That treatment at BUK was at par with WIF at 14 DAE and was significantly higher than all the treatments at DBT. The lowest paddy yield was recorded by WIF until harvest at all the locations.

The result revealed that at BUK the critical time of weed (CTWR) removal, based on 5% allowable yield loss level ended at 10 DAE and the critical weed free period (CWFP) occurred at 66 DAE. At 10% AYL on the other hand, the critical time of weed removal ended at 16 DAE and the critical weed free period occurred at 62 DAE. Based on a 15% AYL, the critical time of weed removal ended at 23 DAE and the critical time of weed free period occurred at 59 DAE. The duration of critical period for weed control (CPWC) is 56, 46 and 36 days for 5, 10 and 15% AYL respectively. The critical date for weeding was 43 DAE. The Maximum rice yield loss due to weed competition was 60.0% (Table 2, 3 and Figure 1).

It could be observed that yield significantly increased with prolonged period of weed free, while lower yield was recorded with increased period of weed infestation and vice-versa. The lowest grain yield was produced by plots with weed infested up to harvest. The result also indicated that the rice grain yield was reduced by the weed infestation and the scale of reduction was found according the duration of weed infestation. Increasing periods of weed interference in the early stages of the rice plants caused a steady decrease in rice yields. Woolley *et al*. (1993) stated that weed dry matter has been found to be highly correlated with crop yield loss. It had also been reported that grain yield is significantly reduced by increasing the weed competition duration (Begum *et al.,* 2008). Similarly, Najib (2009) reported that rice grain yield was significantly affected by weeding interval and as such rice grain yield was drastically decreased as a result of increasing period of weed infestations. In another report by Ekeleme *et al.* (2007) they asserted that rice grain yield was drastically decreased in saturated condition as a consequence of increasing the weed infestations. Knezevic *et al.* (2002) recommended nonlinear regression employing the logistic model for the ‘‘weed-infested interval’’ and the Gompertz model for the ‘‘weed-free interval.’’ The intercepts of these two curves with an allowable yield loss level (AYL) determine the CPWC.

Data on the effect of weed interference on the yield of upland rice at DBT indicated the critical time of weed removal, based on 5% yield loss level ended at 10 DAE and the critical weed free period occurred at 64

DAE. At 10% AYL on the other hand, the critical time of weed removal ended at 16 DAE and the critical weed free period occurred at 61 DAE. Based on a 15% AYL, the critical time of weed removal ended 21 DAE and the critical time of weed free period occurred at 54 DAE. The duration of critical period for weed control is 54, 45 and 33 days for 5, 10 and 15% AYL respectively. The critical date for weeding was 37 DAE. The Maximum rice yield loss due to weed competition was 47.5% (Table 2, 3 and Figure 2)

The onset and end of critical period, which is the duration mandatory for controlling weeds was estimated by the response curve when both curves attained 95 or 90% of the relative yield gain and 5 or 10% of the yield loss of the complete weed free period. The critical period was determined and found to be in between these two threshold points (Getachew *et al.*, 2017) Allowable yield loss of 5%, 10% and 15% was used as threshold point for defining the onset of the critical period of weed removal in this experiment. Johnson *et al*. (2004) also estimated CPWC for lowland irrigated rice as 0–32 DAS in wet season and 4–83 DAS in dry season to obtain 95% yield in West Africa. The onset of the critical period was found relatively stable between seasons, while the end was more variable. This phenomenon is supported by Norsworthy (2004) who opined that the end of CPWC was variable and highly dependent on density, competitiveness, and emergence periodicity of the weed population.

Table 2: Effect of weed interference on paddy yield and relative percentage to weed free of upland rice at BUK and DBT in 2016 raining seasons

Weed interference	2016			
	BUK		DBT	
	Paddy yield (Kgha^{-1})	% weed free	Paddy yield (kgha^{-1})	% weed free
Weed free period (WF)				
14 DAE	1694d	59.7	1290d	65.2
28 DAE	1689d	59.5	1409d	71.3
42 DAE	1873cd	66.0	1454cd	73.5
56 DAE	2348b	82.7	1687b	85.3
Until harvest	2840a	100	1977a	100
Weed infested period (WIF)				
14 DAE	2590ab	91.2	1835bc	93.3
28 DAE	2202bc	77.5	1438cd	72.7
42 DAE	1807cd	67.4	1378d	69.7
56 DAE	1772d	62.4	1268d	64.1
Until harvest	1136e	40.0	1038e	52.5
SE±	265	-	142	-

Means with the same letter in the same column are not significantly different P > 0.05 using DMRT

*DAE – Days after emergence, BUK – Bayero University Kano, DBT – Tomas dam Dambatta, WF –weed free, WIF – weed infested

Table 3: Critical time for weed removal, critical weed free period and critical period of weed control in upland rice base on three levels of allowable yield loss (AYL) at BUK and DBT during 2016 raining season

AYL (%)	Critical time for weed removal (DAE) 2016		Critical weed free period (DAE) 2016		Duration of CPWC (Days) 2016	
	BUK	DBT	BUK	DBT	BUK	DBT
5	10	10	66	64	56	54
10	16	16	62	61	46	45
15	23	21	59	54	36	33

DAE – days after emergence

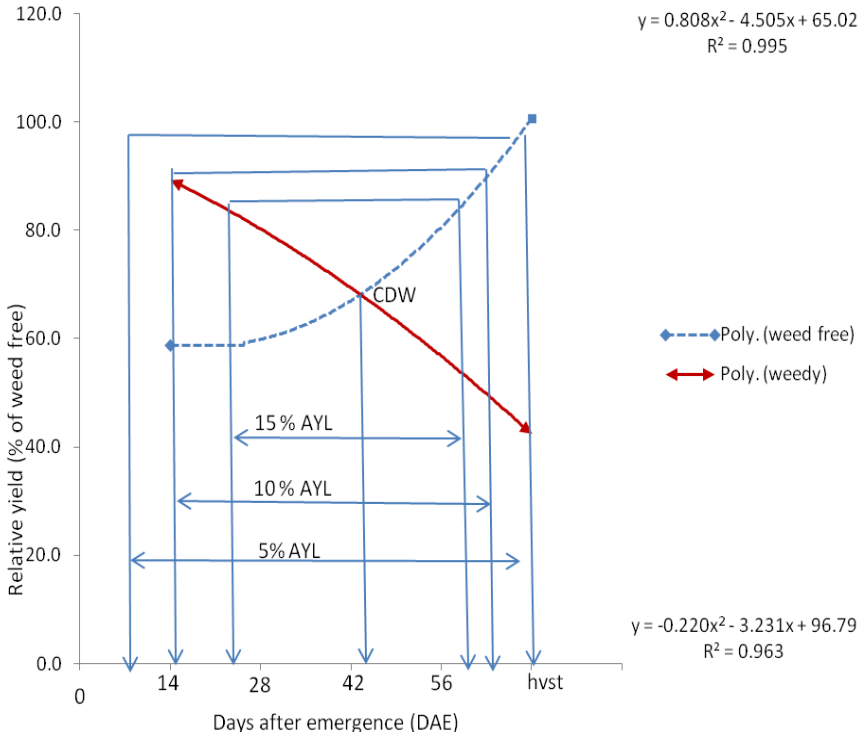

Figure 1: Effect of critical period of weed interference on upland rice yield at BUK in 2016 raining season
AYL – allowable yield loss, hvst – harvest, CDW - critical date for weeding

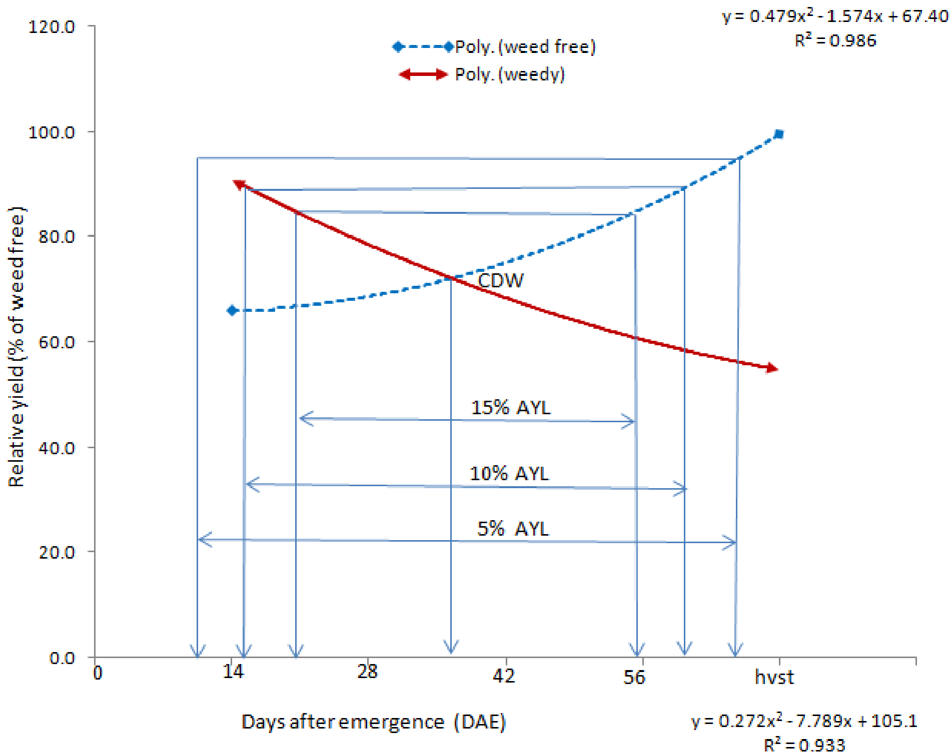

Figure 2: Effect of critical period of weed interference on upland rice yield at DBT in 2016 raining season

VIII. Conclusion

CPWC is highly variable and is largely dependent on the relationship of crop seeding date to the emergence periodicity for the weed community of a particular site. The result of this work indicated that under the similar experimental conditions upland rice field could be kept weed-free during 10 – 66 DAE to achieve 95% of weed-free yield, and 16 – 60 DAE to achieve 90% of weed-free yield, and also 21 – 54 DAE to achieve 85% of weed free yield within the study area.

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