RESPONSE OF UPLAND RICE (*Oryza sativa* L.) TO WEED INTERFERENCE AND CONTROL METHODS IN SUDAN SAVANNA OF NIGERIA

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A RESEARCH THESIS PRESENTED TO THE DEPARTMENT OF AGRONOMY,
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FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN AGRONOMY

DECLARATION

I hereby declare that this research work was conducted and the thesis was written by me under the supervision of Prof M.A. Hussaini and it is a record of my own research work and has not been presented before for the award of any certificate. References and books consulted had been fully acknowledged.

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CERTIFICATION

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APPROVAL

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DEDICATION

This Thesis is dedicated to my family for their support, endurance and prayers in the process of pursuing this certificate.

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- BUK = Bayaro University Kano
- DBT = Audu Bako College of Agriculture Dambatta

ABSTRACT

Recognizing the optimum time for implementing weed management and development of new strategies will help to manage weed in rice. Two experiments were conducted in 2016 and 2017 raining seasons concurrently at Bayero University Kano (11^o 39'N: 08⁰02' E) and Audu Bako College of Agriculture Dambatta (12⁰10' N. 8⁰39' E) Teaching and Research Farms both in Kano State within the Sudan savanna of Nigeria. The aim of the study was to determine the critical period of weed control and the effectiveness of some weed management strategies in upland rice production. The treatments for the first experiment comprised of two sets of weed removal process, involving the weed free periods, where plots were maintained weed free until 14, 28, 42, 56 days after crop emergence (DAE) and until harvest, while the second set namely 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 second experiment consisted of twenty weed control methods: use of Butachlor at two levels i.e. 1.0 and 1.5 kg a.i. ha⁻¹ (pre-emergence); Orizo-plus (2,4-D+Propanil) at two levels i.e. 2.8 and 4.5 kg a.i. ha⁻¹. Rainbow-OD (Penoxsulam) at two levels i.e 0.025 and 0.030 kg a.i. ha ⁻¹ and Solito 320 EC (Pretilachlor + Pyribenzoxim) also at two levels i.e. 0.320 and 0.480 kg a.i. ha⁻¹ (post-emergence). The Butachlor was followed by all the post-emergence herbicides and by supplementary hoe weeding (SHW) at 4 or 8 and at 4 & 8 weeks after sowing (WAS), in addition hoe weeded control (HWC) at 2, 4, 6 & 8 WAS and weedy plots that were employed to serve as control among the treatments. Both experiments were laid out using Randomized Complete Block Design and replicated four times. The results for weed interference indicated rice paddy yield increased with the increasing days of weed-free period and conversely decreased with delay in weed removal, in both seasons and locations. Uncontrolled weed growth up to harvest significantly reduced the rice yield by 60% compared to the paddy yield obtained from the weed-free until harvest. The result further indicated that under similar experimental conditions upland rice field shall be kept weed-free during 16 - 62 and 16 - 61 DAE at BUK and DBT, respectively, in 2016 to achieve 90% of weed-free yield, while in 2017 it shall be during 21-58 and 12-63 DAE at BUK and DBT, respectively, to achieve 90% of the weed-free yield. Similarly, the result for the weed control methods indicated that use of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ resulted in significantly higher number of tillers and panicles per meter square, panicles weight and paddy yield. Based on the findings of this experiment it is recommended that. Upland rice field shall be kept weed-free during 10 – 66 DAE to achieve 95% of weed-free yield. Upland rice farmers shall apply both pre and post emergence herbicides of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹. respectively, for better weed management, or the use of pre-emergence Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, particularly in areas where manual labour is readily available and relatively cheaper. The result also indicated the use of herbicides to be more profitable than other methods of weed control.

CHAPTER ONE

1.0 INTRODUCTION

1.1 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 is consumed by individuals across all levels of incomes. Global land area for paddy production 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). Industry source have estimated an annual average spending on rice importation at \$2 billion USD (CBN news letter, 2015). Rainfed upland rice estimated share is 30% of national rice area and the average yield is 1.9 tonnes ha-1 (Anonymous, 2014). Therefore, the Nigerian government is refocusing attention on stimulating domestic rice production through a number of strategies, such as dry season rice production, expansion of land for rice production, developing new agronomic technologies such as aerobic rice production system, provision of incentive to rice farmers, establishment of local rice processing plants, pest and diseases control and ban on rice importation. 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 it ranks only

second to drought stress. One of the most labour demanding operations in rice production is weed control, and no single weed control method will give satisfactory weed control in all rice ecologies in Nigeria (Ishaya and Dauda, 2010)

Uses of rice vary from cooked rice to specialized rice recipes, breakfast food and snacks. Starch from rice is used in textile industries and dextrin and glucose. Rice is used in making beer, the flour is used in making infant formula and polishing of expensive jewelry. Rice straw is used for livestock feed, bedding materials and organic manure (Nandal *et al.*, 1999). The nutritive values of rice grain are carbohydrate 75%, protein 8% and fat 2.5%. Most of the minerals present in rice are located in the pericarp and germ. Colored rice however, contains more of iron than white rice. The phosphorus content was 4%, it also contains some trace elements like calcium, carotene, thiamine, riboflavin and niacin. Rice grain contains enzymes like amylases, lipases, oxidases, peroxidases phenolases, etc. However, on storage most of enzymes activities decrease (Chandrasekaran *et al.*, 2011).

One of the important things on increasing rice production is to minimize crop loss which is caused by weed competition because weeds do not only reduce the rice production but also have an adverse effect on rice grain quality. Farmers average yield in Nigeria is 3,000kg ha⁻¹ for swamp rice and 1,500kg ha⁻¹ for upland rice (Anonymous, 2014). Many farmers have depended on herbicides for weed control. Herbicides such as 2,4-D, Butachlor, Propanil, Imazapyr, Oxidiazone, Pendimenthalin, Thiobencarb, Pretilachlor, Quinclorac, Fenoxaprop-ethyl, Glyphosate etc are often used to control weed in rice. Herbicides bring about various physiological and biochemical effects on the growth and development of emerging seedling as well as established weed plants, either

after coming into contact with plant surface or after reaching the sites of action within the plant tissues. However, weed species resistant to herbicides have been reported in countries with high adoption rates including the Philippines (Migo *et al.*, 1986), Malaysia (Watanabe *et al.*, 1997), Japan (Itoh *et al.*, 1999) and Korea (Park *et al.*, 1999). Herbicide resistance in weeds might develop due to repeated use of the same herbicides, either within a weed spectrum or within a weed species; it may develop slowly or rapidly (Kim, 1996).

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 interference. Information on the critical period of weed competition in direct-seeded rice could help improve timing of post emergence herbicides application. Reducing the number of herbicide treatments as a result of better timing and efficiency may reduce potential environment contamination and the selection pressure for herbicide resistant weeds. Moreover, to give more precise recommendation to growers, such a critical period must be worked out for specific rice cultivars grown in a particular region keeping in view the floristic composition of weeds and climatic conditions.

1.2 STATEMENT OF THE PROBLEM

Weeds are the most threatening biological constraints to direct seeded rice cultures (Rao *et al.*, 2007). Rice yields might be reduced up to 60% or even a complete crop

failure may occur due to heavy weed infestation (Chae and Ghu, 1999). Cultural, chemical and integrated methods are generally employed to control weeds. Manual weeding though effective is getting increasingly difficult due to labour scarcity especially at the time of need during peak period of weed infestation, the drudgery and cutting of plants roots and stands combined with the rising wages and its dependence on weather conditions. Thus, herbicides usage seems indispensable for weed management in direct seeded rice (Azmi *et al.*, 2005). Weed management in direct seeded systems is more critical than transplanted systems as weeds in direct seeded system can emerge at the same time or before the rice plants, resulting in a serious problem of competition (Johnson *et al.*, 2004). Weed species resistant to herbicides have been reported in countries with high adoption rates and this might be as a result of the use of the same herbicides for long time. Productivity of direct-seeded rice is believed to be largely dependent on effective and timely weed control. This, in turn requires knowledge about critical period of weed competition which is lacking among most rice farmers in Nigeria.

1.3 JUSTIFICATION OF THE STUDY

Rice production under current inputs and technologies will not meet projected population growth. Rice production must increase by 36% by 2025 to feed an estimated 4 billion rice consumers in the world (Anderson *et al.*, 1997). Meeting such present and future demand will require increased use of inputs and technologies to improve yields (Rice Today, 2010). Many of the issues related to direct seeded rice (DSR) still remain unaddressed and a lot of work remains to be done to develop technologies which are site-specific, effective and economically viable. Weed control in upland rice involve a lot of human resource to carry out in Nigeria. Idem and Showemimo (2004) reported that hand

weeding which is the common weed control practice among peasant farmers can consume as many as between 250 and 780 man-days ha⁻¹, all of which increases the cost of production, depending on frequency of weeding, ecosystem, and environmental conditions during cropping. Kebede (2001) also indicated that growth in production can be gained through the use of technologies and allocative efficiencies of farmers in response to the changing techniques and production environment. Hence, adoption of technologies should lead to substantial yield increase. An effective early weed management strategy is imperative for any rice production system aiming at achieving higher productivity and profitability (Jayasuria et al., 2011). Many farmers have depended on herbicides for weed control, however, weed species resistant to herbicides have been reported in countries with high adoption rates. Therefore, there is the need to develop sustainable weed management approaches that will integrate a variety of agronomic practices, and use of different types of herbicides combination and rates that can help to suppress weed competition and minimize herbicide resistance in weed common to rice field.

Precise knowledge on critical period of weed competition of upland rice especially the interspecific rice varieties known as New rice for Africa (NERICA) are still scanty in Africa (Wopereis *et al.*, 2008). Knowing the critical period of weed control (CPWC) is useful in making decisions on the need for and appropriate timing of weed control and for achieving efficient herbicide use from both biological and economic perspectives. Critical period of competition varies from crop to crop depending on weed emergence time, weed type, weed density and management practices. It is important to determine critical period of weed-crop competition to plan effective weed control strategy (Mubeen

et al., 2009). In order to provide more precise information for growers, CPWC should be determined specifically for a particular region and crop by considering the weed composition and climatic conditions (Knezevic et al., 2002).

1.4 AIM AND OBJECTIVES OF THE STUDY

The aim of the study was to determine the critical period and the effectiveness of some weed management practices in upland rice production. While the specific objectives are:

- > To determine the critical period of weed interference in upland rice production system in Sudan savanna of Nigeria
- > To determine the effectiveness of each of the herbicides used over the farmer's practice of hoe weeding in the study area.
- > To identify appropriate and most effective weed management strategies in order to suppress weed for uptimum yield.
- To determine the economic advantage of the use of herbicides over manual weed control in upland rice production system

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 DIRECT SEEDING SYSTEM OF RICE PRODUCTION

Direct seeding refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting. Once germination and seedling establishment are completed, the crop can remain rainfed, the upper surface soil layers fluctuating from aerobic to nonaerobic conditions. Direct seeding of rice seems to be a viable alternative in rescuing farmers (Farooq *et al.*, 2011). This is because it has potential for attaining high water productivity and eliminating the possible edaphic conflicts in rice-wheat production in sub tropical region of West Africa by utilizing the residual moisture at the end of the rainfed rice culture which coincides with the period of wheat establishment. Direct seeded rice is coming up in a big way due to many advantages over transplanting system such include less water requirement, absence of nursery raising, puddling and transplanting leading to saving in cost of cultivation.

2.2 NATURE OF CROP - WEED COMPETITION

Weeds are self-grown and appear simultaneously with crop plants creating severe competition for nutrient, space, moisture and solar energy resulting in low yield of crop. The inherent size differences between rice seedlings and emerging weed species that confer a competitive advantage to transplanted rice is removed when direct seeding is practiced. Relative outcomes of competition between a weed species and direct seeded rice are, however, influenced by weed species and rice cultivar, weed and crop density, and competition duration as governed by the selective removal of the weed species, along

with associated agronomic and cultural management factors (Umapathy and Sivakumar, 2000). Grassy weeds are heavy competitors with rice crop and are followed by sedges and broad leaved weeds (Tomita *et al.*, 2003). Chauhan and Johnson (2010) stated that when direct seeded rice was grown together with either jungle rice or *Ludwigia* spp, shoot competition reduced the growth and yield of rice more than root competition and rice grain yield was highly correlated with above and below ground biomass of the weeds.

Weeds usually grow faster than the crop plants and absorb added nutrient more rapidly and in larger quantities than by crops (De Datta and Baltazar, 1996 Gitsopoulo and froud-william 2004) and thus deprive the supply of nutrients in time to the crop plants. Weeds removed nutrients (N, P and K) eight times higher under direct seeded rice compared to that of puddled transplanting (Singh *et al.*, 2002). Sudhalakshmi *et al.* (2005) reported that, nutrient uptake by weeds was 30 kg N, 10 kg P and 17 kg K per hectare in transplanted rice in clay loam soil which is comparatively less in direct seeded rice. Puniya *et al.* (2007), however, noticed that the highest loss of nutrients (N 42.07, P 10.00 and K 21.80 kg ha⁻¹) occurred with unweeded control due to more density and dry weight of weeds in rice field.

2.3 EFFECT OF WEED CONTROL METHODS ON RICE PRODUCTION

Rao *et al.* (2007) described various weed management strategies practiced in DSR, which include agronomic practices as land preparation, seeding rates, fertilizer application, water management, competitive cultivars, as well as manual, mechanical, and chemical weed control. The choice of the weed management methods depends upon climatic conditions, soil type, technology available, type of rice culture, the farmer's

economic situation and yield target, and is evaluated in terms of the cost of weed control in comparison with the estimated value of the resulting yield increase (Sinha Babu *et al.*, 1992). Manual weeding, although efficient in controlling weeds, has been restricted due to several economical and technological factors (Khaliq *et al.*, 2012). This is similar to the findings by Ishaya (2004) he stated that, weed competition decrease growth and yield of rice plant due to intense competition for soil resources. Estimation of yield losses caused by competition from weeds ranges from 30-100% (Dobermann and Fairhurst, 2000).

Wide range of herbicides is available for the management of grassy weeds (Pretilachlor, Butachlor, Anilofos and Oxadiargyl) as well as broad-leaved weeds (Methyl sulfuron, Chlorimuron, Ethoxysulfuron and 2, 4-D). Pendimethalin, Butachlor, Oxadiazon and Nitrofen were among the herbicides which have been tested worldwide for controlling weeds and improving the yield of direct seeded rice (Rao et al., 2007; Faroog et al., 2011). Herbicides recommended against grassy weeds are mostly used as pre-emergence and weeds emerging later in the season often get escaped (Yadav et al., 2008). Many times due to various constraints at farm level, the application of herbicides in the early growth stages is not possible and continuous use of same herbicide might cause resistance in weeds. Pre-emergence Butachlor application at 1.5 kg/ha 3 DAS + hand weeding at 40 DAS was also found to record significantly higher crop growth attributes viz., plant height, number of tillers and plant dry weight as compared to unweeded control. Higher weed control efficiency resulted in lower crop-weed competition effecting better crop growth, induces greater tiller production and biomass yield (Amador-Ramírez, 2002),

Over the years, chemical weed control in DSR has emerged as promising solution of weed problem and expanded manifold as it is easy, quick, economical and feasible. Several pre-emergence herbicides applied either alone or supplemented with hand weeding have been reported to provide fairly adequate weed suppression in DSR (Pellerin and Webster, 2004). There is a relationship between the timing of weed emergence and the pressure exerted to the crop through competition and resultant losses in crop yield. Yield losses are usually higher when weeds emerge earlier or at the same time as the crop (Aldrich, 1987). In field trials of direct-seeded irrigated rice, 95% of weed-free rice yield was obtained when weeds were controlled up to 32 days after sowing (DAS) in wet season and 83 DAS in dry season (Johnson et al., 2004). Degree of competition offered by a crop can influence the herbicide performance (Khaliq and Matloob, 2011). Many of the issues related to DSR still remain unaddressed and a lot of work remains to be done to develop technologies which are site-specific, effective and economically viable. Large scale adoption of DSR in Pakistan is restricted largely due to unavailability of a potential weed control strategy available locally (Khaliq *et al.*, 2012).

2.4 EFFECT OF WEED CONTROL METHODS ON WEED GROWTH

Weed management practices had significant effect on all weed attributes such as weed population, weed dry weight and weed control efficiency (WCE). Wide range of herbicides is available for the management of grassy weeds (pretilachlor, Butachlor, anilofos and oxadiargyl) as well as broad-leaved weeds (methyl sulfuron, chlorimuron, ethoxysulfuron and 2, 4-D). Herbicides recommended against grassy weeds are mostly used as pre-emergence and weeds emerging later in the season often get escaped (Yadav *et al.*, 2008). Many times due to various constraints at farm level, the application of

herbicides in the early growth stages is not possible and continuous use of same herbicide might cause resistance in weeds Weed population and weed dry weight were recorded to be significantly highest for unweeded control (Aldrich, 1987). Hasanuzzaman et al. (2007) also reported that, weed density was significantly greater in unweeded plots than other treatments. Weed control treatment by hand weeding at 20 & 40 DAS registered significantly lower weed population and weed dry weight over pre-emergence Butachlor application at 1.5 kg/ha at 3 DAS + hand weeding at 40 DAS (Johnson et al., 2004). This may be due to the fact that manual removal of weed at 40 DAS might have effectively controlled the growth of weed in the former case whereas, decreasing efficiency of Butachlor with the lapse of time may have attributed for higher weed growth in the later case. Similar results were also reported by Bikash et al. (1986) who reported that hand weeding was most effective in controlling all three types of weeds viz. grasses, sedges and broad leaved when compared with different herbicides in rice fields. At subsequent stages of observations both the weed management treatments were at par with each other and recorded significantly lower weed population and weed dry weight over unweeded control. This was in agreement with the findings of Singh and Patel (1989). Ultimately, significantly higher WCE was recorded by hand weeding at 20 & 40 DAS over preemergence Butachlor application at 1.5 kg ha⁻¹ at 3 DAS + hand weeding at 40 DAS.

2.5 PHYTOSOCIOLOGICAL WEED CHARACTERISTICS AND RICE GROWTH

Weed phytosociological characteristics entails the study of weed distribution, description, classification and overall information of all the weed species in a community of plant population and compare and classifies weed in a crop-weed ecosystem (Zimdhl, 2007; Das, 2011). Although weed-crop competition reduces the yield and other yield

component of rice but mere presence of weed without considering their density and threshold effect on crop will not be economical to start the process of controlling it.

Understanding abundance and distribution of weed species within the landscape of an agroecosystem is an important goal for weed science. The study of weed population's abundance and distribution is helpful in determining how a population changes over time in response to selective pressures applied by our agronomic practices. Accurate estimates, however, of these two key variables are very important if we are to manage agricultural land both for productivity and for biodiversity. Biodiversity is generally thought of in terms of number of species and their relative proportion within the plant community (Das, 2008). Generally agronomic practices, including the use of available technologies such as herbicides, limit plant diversity within our cropping systems. Weed species that are able to survive these agronomic selective pressures are ecologically well adapted and invariably become more difficult to manage. In addition, low plant diversity within an agroecosystem can result in the agroecosystem becoming more vulnerable to invasion by new weed species (Roger *et al.*, 2015; Singh and Patel, 1989)

2.6 HERBICIDE ACTION ON WEED AND RICE GROWTH

Application of some pre-emergence herbicides including pedimenthalin, Butachlor, Thiobencarb, Oxadiazon, Oxyfluorfen and Nitrofen were found to provide a fair degree of weed control in wet direct seeded rice (Pellerin and Webster, 2004). But, application duration of all those pre-emergence herbicides is very narrow, usually 0 to 5 days of seeding, and they require adequate moisture during their application which some time not be available after sowing. Therefore, under aerobic soil conditions postemergence herbicides may perform better (Mahajan *et al.*, 2009). Among the post

emergence herbicides Ethoxysulfuron Cyhalofop-butyl, Pritilachlor, Chlorimuron, Methyl sulfuron, Bispyribac sodium, Penoxsulam effectively controlled weeds in direct seeded rice (Mann *et al.*, 2007; Singh *et al.*, 2008; Mahajan *et al.*, 2009 and Juraimi *et al.*, 2010). The repeated use of same herbicide causes herbicide resistance in weeds (Kim, 1996) and therefore, alternate application of herbicides with different modes of action would necessarily be needed to combat this troublesome situation. Application of different herbicides as proprietary or tank mixture could help to prevent resistance problem as well as shift in weed population, which is always associated with the use of a single herbicide (Wrubel and Gressel, 1994). Kim and Im (2002) reported that, Bensulfuron-methyl is active against broad-leaf weeds but application of Bensulfuron-methyl mixed with 2, 4-D has broader weed control spectrum.

The success of DSR is dependent upon weed control with herbicides. However, herbicides should not be regarded as replacements for other weed control practices but should be used in conjunction with them. Herbicide use should be justified to coincide with the presence of sufficient weeds so as to warrant treatment, and should be used when weeds are most vulnerable. The optimum herbicide rate depends on factors such as cultural practices, soil type, and environmental conditions. Factors which must be considered when developing a herbicide program are the availability of herbicides, incidence of weed flora, application method and time, crop tolerance level, and cost effectiveness. The use of herbicides ensures effective weed control during periods of labour shortage when weeding coincides with other farm work. Temporary rice injury manifested as leaf chlorosis and inhibition of plant growth frequently occurs, but the crop usually recovers after two to three weeks and produces desired grain yield.

Recently, sequential spray of pre-emergence application of Pendimenthalin (1.0 kg ha⁻¹) followed by Bispyribac sodium (0.030 kg a.i. ha⁻¹) at 15 DAS was found to effectively control weeds in DSR (Mahajan *et al.*, 2009). Danmaigoro *et al.* (2012) applied 1.2+0.8 Kg a.i.ha⁻¹ of Orizoplus (propanil + 2-4 D) and recorded significantly larger leaf area, high leaf area index, higher crop growth rate, relative growth rate, net assimilatory rate and grain yield of rice than the other rates but were comparable with the hoe weeded control. Other herbicides that are found effective in DSR are Pyrazosulfuron and Oxadiragyl as pre-emergence and Azimsulfuron, Penoxsulam, Cyhalopfop-butyl, and Ethoxysulfuron as post-emergence (Rao *et al.*, 2007). It must never be overlooked that all pesticides are toxic; they must be handled safely so as to reduce or avoid excessive and costly wastes, environmental concerns, crops damage, to adjacent crops by spray drift, injury to the applicator, excessive contamination and residues, and injury to beneficial organisms. It is advisable to rotate the herbicide combination in each year for delaying the development of herbicide resistance in weed

2.7 EFFECT OF MANUAL WEEDING ON RICE PRODUCTIVITY

Hand weeding is very easy and environment-friendly but tedious and highly labor intensive. Farmers very often fail to remove weeds due to unavailability of labor at peak periods. Moreover, morphological similarity between grassy weeds and rice seedlings makes hand weeding difficult at early stages of growth. Considering all these situations, herbicide is being considered as the most practical, effective and economical means of weed management in rice (Kebede, 2001). Despite some adverse environmental impacts, no viable alternative is presently available to shift the herbicide dependence for weed management in rice.

It seems possible that weeds grown at early stages can be reduced to a minimum by pre-emergence application of herbicide and removal of late emerged weeds by supplemental hand wedding (Sharma et al., 1999). The combination of herbicides and manual weed control has significant effect on controlling weed of rice (Moody and De Datta, 1986; Singh et al., 2005). However, Chander and Pandey (2001) observed that, hand weeding increased grain as well as straw yields compared to herbicides and weedy check because of frequent elimination of weeds that resulted in the reduced weed competition. Nonetheless all these situations, herbicide is being considered as the most practical, effective and economical means of weed management in rice (De Datta, 1996). Despite some adverse environmental impacts, no viable alternative is presently available to shift the herbicide dependence for weed management in rice. Many herbicides are effective against many weeds but some weeds which are not affected by herbicides must be eliminated mechanically as the weeds which survive or emerge after the herbicide treatment may grow vigorously due to less competition from other weeds (Singh et al., 1994).

2.8 EFFECT OF TIME OF HERBICIDE APPLICATION ON RICE PERFORMANCES

Post-emergence herbicides are a major tool used to control weeds in DSR. The growth stage of weed species may have an effect on herbicide efficacy by influencing uptake and metabolism of herbicides (Singh and Singh, 2004). Diclofop, for example, was more effective on green foxtail (*Setaria viridis* (L.) Beauv.) and wild oat (*Avena fatua* L.) when applied at an early growth stage (Friesen *et al.*, 1976) Conversely, trifloxysulfuron was more effective on yellow nutsedge (*Cyperus esculentus* L.) at late application stages (Singh and Singh, 2004). Generally, the herbicide efficacy is lower

when applied on bigger weeds. The herbicide degradation rate may be faster in big plants, and herbicide rates may need to be increased to achieve the same level of control (Singh and Singh, 2004) In addition, reliance on a single herbicide may result in evolution of herbicide resistance in weeds and shift in weed flora. In Sri Lanka, for example, continuous use of bispyribac-sodium to control propanil-resistant barnyardgrass has resulted in a shift to dominance by Chinese sprangletop in rice (Marambe, 2002). There are reports from India that Chinese sprangletop is poorly controlled by bispyribac-sodium (Gopal, 2010). Therefore, optimum time of herbicide application and range of herbicides may help control these weeds effectively.

2.9 ECONOMICS OF DIFFERENT WEED MANAGEMENT PRACTICES

Hand weeding is laborious and generally more expensive. The weed control cost is maximum for hand weeding (two hand weeding at 30 and 45 DAT) and the lowest for chemical weed management (Hasanuzzaman *et al.*, 2007). Application of Almix 20 WP at 0.04 kg a.i. ha⁻¹ as post emergence herbicide at 15 DAT in transplanted rice resulted in highest benefit cost ratio in comparison to hand weeding (Pal *et al.*, 2009). Modern agriculture is productivity oriented and emphasize on economic viability and sustainability of the system. Such an approach demands a weed management strategy that is selective, efficient and cost effective with little or no adverse ecological effects. The economic evaluation of any technique is also essential for its adoption at farmer's level. Direct seeding rice cultures face severe weed infestation and there is need to look for various approaches for their control. Evaluation of bio economic efficiency of different weed control methods in dry seeded rice will help to reduce the cost of production which may lead to higher profit index. Use of herbicide was an efficient and cost-effective

method for weed control in dry seeded rice. Manual weeding can be adopted where cheap labour is available.

2.10 THE TEST HERBICIDES

2.10.1 Butachlor (EC)

The generic name is (N- butoxymethyl 2-chloro 2, 6-methyl acetinilide). It is generally used as pre-emergence herbicide in cereal crops like rice, millet, sorghum, etc (Akobundu, 1987). It has soil half life of 60 days depending on the environmental conditions and an oral LD50 (rat). It is formulated as EC500 mg/l and sold under trade of Butastar by African Agro Company. It was reported that Butachlor has good crop tolerance which makes it suitable for use in rice based cropping system. The mode of action is the inhibition of protein synthesis, auxin production and cell expansion possibly by preventing the transfer of amino – acetyl RNA to the polypeptide chain (Ashton and crafts, 1981). It was shown that Butachlor applied at 3.3 kg a.i.ha⁻¹ produced comparatively higher yield of rice than the two hoe weeding at Badeggi (Imeokparia, 1989). In another report Mahadi (2004) observed increase in grain yield of rice by applying Butachlor at 1.0 and 1.5 kg a.i. ha⁻¹. Sreedevi *et al.* (2001) observed that pre-emergence application of Butachlor at 1.5 kg a.i. ha⁻¹ recorded lower weed dry weight (120 g m⁻²) and higher grain yield (2.87 t ha⁻¹) in wet seeded rice.

2.10.2 Orizo-plus EC (2,4-D + Propanil)

This is a selective post emergence herbicide for weed control in rice. It comprises a mixture of 2,4-D (200 g l⁻¹) and propanil (300g l⁻¹) and is effective in controlling grasses, sedges and broad leaves weeds when applied at 3 weeks after emergence of rice and weeds (Das, 2011). It has soil half life of 60 days depending on the environmental

conditions and an oral LD50 (rat). It is formulated as EC 500 mg/l and sold under trade name of Orizo-plus by Candel Nigeria limited. The mode of action is through the inhibition of photosynthesis process in the affected plant. The manufacturers' recommendation is $2.5 - 4.0 \, \text{kg}$ a.i. per hectare.

Propanil (EC)

The generic name is 2-chloro-N-(methylethyl)-N- phenylacetamide. It has soil half life of 60 days depending on the environmental conditions and an oral LD50 (rat). It is formulated as EC500 mg/l and sold under trade name of Properforce. It is another selective post emergence herbicide highly effective on grasses and sedges (Echionocloa crusgalli, Echionocloa colomum, Digitaria horizontalis, Bracharia deflexa, etc) (Akobundu, 1987). Propanil is a contact herbicide that causes chlorosis, necrosis, destroying root permeability and dying of cells. It is applied post emergence at 3.0 - 5.0 kg ai ha⁻¹ in rice. Propanil was also used to effectively control weed in rainfed lowland rice when applied at 0.76 to 2 kg a.i ha⁻¹ and 1.73 to 2.2 kg a.i. ha⁻¹ at 7 and 21 DAS, respectively (Akobundu, 1987).

2, 4 – D (EC) (2,4-Dichlorophenxy acetic acid)

This is a highly selective post emergence herbicide effective on broad leaved weeds (Das, 2011), used for the control of many annual weeds in cereals crops like sugar-cane, rice, millet, wheat etc and non crop area. It has soil half life of 60 days depending on the environmental conditions and an oral LD50 (rat). It is formulated as EC280 mg/l and sold under trade name of Super amine. The mode of action is the blockage of the plant merismetic tissues which causes non supply of nutrients and the plant will die of starvation. 2,4-D is exclusively effective on broad leaved weed such as *Amaranthus*

spinosus, Ludwigia parviflora, Digitaria avensis, Striga spp, etc. The manufacturer's recommendation is 0.5 - 1.5 kg a.i. ha^{-1} .

2.10.3 Rainbow OD (Penoxsulam)

Penoxsulam is a new acetolactate synthase (ALS) inhibitor herbicide for postemergence control of annual grasses, sedges and broadleaf weeds in rice culture (Jabusch and Tjeerdema, 2005). It has soil half life of 45 -70 days depending on the environmental conditions and an oral LD50 (rat). It is formulated as 25OD mg/l and sold under trade of Rainbow. It contains 25g per liter penoxsulam oil dispersable (OD). It is highly effective on Cyperus difformis, Fimbristalis spp. Echinochloa spp. dicotyledonous weed such as Heteranthera spp, Masilea minuta, Sphenochlea zeylanica, Ludwigia spp. Yadav et al. (2007) have also reported penoxsulam as an effective post-emergence herbicide against mixed weed flora in rice. Efficacy of penoxsulam in controlling weeds and increasing rice grain yield was also reported by Jason et al. (2007) and Mishra et al. (2007). Singh et al. (2007) reported that comparatively lower doses of Penoxsulam could be used when it was applied at early post-emergence (8-12 DAT). It may be concluded that Penoxsulam application at 25.0 g/ha as pre-emergence (3 DAT) and 20.0-22.5 g/ha as post-emergence (10-12 DAT) is needed for satisfactory weed control in transplanted rice and to realize better rice yields without any residual toxicity of Penoxsulam on succeeding crop (Mishra et al., 2007)

2.10.4 Solito 320 EC (Pretilachlor and Pyribenzoxim)

This is a post emergent herbicide good for the control of weed in direct seeded upland rice. It contains an active ingredient of Pretilachlor 300g and Pyribenzoxim 20g per liter. It has soil half life of 60 days depending on the environmental conditions and an

oral LD50 (rat). It is formulated as 320EC mg/l and sold under trade of Solito. Reddy (2010) reported that application of Pretilachlor + safener at 0.45 kg ha⁻¹ at 3 DAS and manual weeding at 45 DAS recorded higher weed control efficiency of 86.7% which lead to highest grain yield of 6,216 kg ha⁻¹ in direct seeded rice. In another work Babar and Velayutham (2012) observed that, application of Pretilachlor at 0.75 kg a.i. ha⁻¹ as preemergence + 4 times manual weeding from 10 DAT at 10 days interval was found to be more effective in controlling weeds (95.7 - 99.5% WCE) under System of Rice Intensification (SRI). Pretilachlor with safener at 0.500 kg a.i. ha⁻¹ applied at 3 DAS/DAT and Chlorimuron + Methtyl sulfuron at 4 g a.i. ha⁻¹ applied at 21 DAS/DAT followed by manual weeding at 35 DAS/DAT could effectively control all the weeds (Singh *et al.*, 2008). Ishaya and Dauda (2010) applied 2, 4-D + Propanil at 1.44 + 0.8 kg a.i ha-1 and Butachlor + Propanil at 2.4+0.8 kg a.i ha-1 to the crop, resulted in significantly higher dry matter weight of rice than the application of the same rates of nitrogen fertilizer with pendimenthalein and 2, 4-D.

2.11 CONCEPT OF CRITICAL PERIOD OF WEED CONTROL IN RICE

The critical period for weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses. Zimdahl (1988) defined it as the period during which weeds must be controlled to prevent economic yield loss. 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). Crop cultivars differ regarding their competitive ability against weeds and degree of competition offered by a crop determines the level of weed control achieved with herbicides. Productivity of direct-seeded rice is believed to be largely dependent on

effective and timely weed control. 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. Reducing the number of herbicide treatments as a result of better timing and efficiency may reduce potential environment contamination and the selection pressure for herbicide resistant weeds. Moreover, to give more precise recommendation to growers, such a critical period must be worked out for specific rice cultivars grown in a particular region keeping in view the floristic composition of weeds and climatic conditions. Very little is known about critical period of weed competition in upland rice cultivars of Nigeria under direct-seeded rice culture. Examples of historical reasons for studying this concept include

- (i) The potential to reduce the amount of herbicide used by achieving optimal application timing (Hall *et al.*, 1992; Van Acker *et al.*, 1993; Zimdahl, 1980),
- (ii) The potential to reduce environmental and ecological degradation associated with the prophylactic use of herbicides (Swanton and Weise, 1991).
- (iii) To provide a test to determine whether the methods of weed control are based on biological necessity (Weaver, 1984).

Most recently, there is a need for the economic optimization of weed control tactics in herbicide-tolerant crops (HTCs) through timely application of post emergent herbicides. It is contend by many weed scientists that knowing the CPWC in major crops can aid in making decisions on the need for and timing of weed removal in cropping systems that use both HTCs and conventional crop cultivars. In essence, the CPWC

represents the time interval between two separately measured crop-weed competition components:

- (a) The critical timing of weed removal (CTWR) or the maximum amount of time early-season weed competition can be tolerated by the crop before the crop suffers irrevocable yield reduction.
- (b) The critical weed-free period (CWFP) or the minimum weed-free period required from the time of planting to prevent unacceptable yield reductions.

The former component is estimated to determine the beginning of the CPWC, whereas the latter determines its end. Results from both components are combined to determine the CPWC. The beginning and duration of the CPWC can vary depending on several factors, including the characteristics of the crop and the weeds, the environmental variables, the cultural practices, and the assumptions made regarding the methods employed to determine the CPWC (Hall et al., 1992). Theoretically, weed control before and after the CPWC may not contribute to the conservation of the crop yield potential. The beginning and end of the CPWC determined using the functional approach will depend on the level of allowable yield loss (AYL) used to predict its beginning and end. Many studies reported anywhere from 2 to 5% as the maximum AYL (Hall et al., 1992; Van Acker et al., 1993). But the AYL can be adjusted depending on the cost of weed control and the anticipated financial gain. For example, depending on the market price of the crop and the cost of weed control, the AYL can be adjusted for a particular field. This is easily achieved by selecting AYL from the regression curves according to the economic risk one is willing to take.

2.12 EFFECT OF CRITICAL PERIOD OF WEED CONTROL ON RICE PRODUCTIVITY

Rice grain yield decreased with prolonged delays in weed removal; conversely, grain yield increased with the increasing length of weed-free period (Van Acker et al., 1993). Weed competition throughout reduced crop yield by approximately 55% as compared with season long weed-free period. These values are very close to those reported in previous studies where season long weed competition reduced yield by approximately 50% (Johnson et al., 2004). Juraimi et al. (2009) recorded 79 and 66% yield reduction in rice due to weed competition till harvest in flooded and saturated conditions, respectively. Chauhan and Johnson (2011), on the contrary, reported as high as 95% yield reduction in aerobic rice due to weed competition throughout the crop growing season. These contrasting findings might be due to differences in rice variety, agroclimatic conditions, soil moisture regimes, and weed flora among the experimental sites. Prolonged weed competition resulted in reduced biomass accumulation and lesser panicles per m², grains per panicle, and thousand-seed weight which ultimately translated into lower grain yield. Increased biomass accumulation by weeds with the increasing span of weed interference period might also be a plausible cause of yield reduction in rice. As Woolley et al. (1993) stated, weed dry matter has been found to be highly correlated with yield loss in rice. In West Africa, Johnson et al. (2004) estimated CPWC for lowland irrigated rice as 0-32 DAS in wet season, while 4-83 DAS in dry season to obtain 95% yield. In Malaysia, based on the 5% yield loss, Begum et al. (2008) concluded that flood-irrigated rice must be kept weed-free from 14 to 28 DAS, while

Juraimi *et al.* (2008) suggested that, direct-seeded rice should be kept weed-free for 2–71 DAS in saturated condition and 15–73 DAS in flooded condition. In the Philippines, Chauhan and Johnson (2011) estimated CPWC of rice as between 18 and 52 DAS to obtain 95% of weed-free yield.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITES

The experiments were conducted in 2016 and 2017 raining seasons at two locations concurrently i.e. Bayero University Kano (BUK) Teaching and Research Farm (11⁰ 39'N;08"02 elevation) in Ungogo Local government Area and Audu Bako College of Agriculture (DBT) Research Farm Thomas Dambatta (12⁰10' N, 8⁰39' elevation;) in Makoda Local Government Area both in Kano State within the Sudan savanna agroecological zone of Nigeria.

3.2 WEATHER RECORDS

Weather parameters such as mean annual rainfall, minimum and maximum temperatures for BUK during 2016 and 2017 raining season were collected from the Centre for Dryland Agriculture (CDA) Bayero University Kano weather station while for Audu Bako College of Agriculture Research Farm Thomas Dambatta (DBT) were obtained from the weather station of Audu Bako College of Agriculture, Dambatta.

3.3 SOIL CHARACTERISTIC OF THE SITES

Soil samples from the expiremental sites were collected with a soil auger before land preparation during both seasons at a depth of 0 – 30cm from randomly selected points. The soil samples collected were bulked and air dried, and sieved with a 2mm sieve for laboratory analysis. Particles size analysis was done by standard hydrometer method (Day, 1965), organic carbon was measured by dichromate digestion (Walkey and Black, 1954). The soil pH was measured by placing a glass electrode in a mixture of soil and deionized water. (Black, 1965), total nitrogen was determined by the Micro kjeldhel

extraction whereby the carbon and nitrogen content were determined by instrumentation heating of the solid sample in a highly concentrated oxygen environment, thereby combusting the reduced carbon compounds and liberating carbon monoxide, carbon dioxide, and nitrogen oxides. Depending on the instrumentation, the gasses are then passed over a series of reducing or oxidizing reagents/catalysts, water and ash separators or gas splitting devices as described by Bremer, (1965). Nitrate is determined by reduction to nitrite (NO2-N) via a cadmium reactor, diazotized with sulfanilamide and coupled to N-(1-Napthyl)-ethylenediamine dihydrochloride to form an azochromophore (red-purple in color) which is measured spectrophotometrically at 520 nm. Available P was determined by the use of Bray method (Bray and Kurtz, 1945). Exchangeable bases were determined in NH₄OAC extract (Black, 1965) and by atomic spectrophotometer for calcium and magnesium. Sodium and potassium were determined by Flame photometer while CEC was estimated by summation. The soil CEC was determined by fractioning the humus into humic and non-humic materials based on solubility in acid or alkali solutions. Humic and fulvic acids are the major components of the humic material. Humic matter (HM) is based on alkali and alcohol extraction of soil organic matter and subsequent determination by absorbance transmission using a colorimeter.

3.4 TREATMENTS AND EXPERIMENTAL DESIGN

The study was conducted in two sets of experiments; the first experiment was determining the critical period of weed interference and the second was testing the performance of different weed control strategies.

3.4.I Experiment I

This comprised of two sets of weed removal treatments. The first consisted of weed free periods where plots were maintained weed free at 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 at 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.

Periods for weed interference in experiment I:

Set of weed free treatments

Set of weed infested treatments

Weed free at 14 DAE

Weed infested at 14 DAE

Weed free at 28 DAE

Weed infested at 28 DAE

Weed free at 42 DAE Weed infested at 42 DAE

Weed free at 56 DAE Weed infested at 56 DAE

Weed free until harvest Weed infested until harvest

3.4.2 Experiment II

This consisted of twenty weed control strategies as listed below. The experiments was laid out using Randomized Complete Block Design and replicated four times. The preemergence Butachlor was applied a day after sowing while the post-emergence herbicides were applied at 4 weeks after sowing (WAS).

Details of herbicides treatment combinations and active ingredients for experiment II

Butachlor at 1.0 kg a.i. ha⁻¹ fb Orizo-plus at 2.8 (1.8 Propanil +1.0 2,4-D) kg a.i. ha⁻¹ Butachlor at 1.0 kg a.i. ha⁻¹ fb Orizo-plus at 4.5 (2.88 Propanil +1.6 2,4-D) kg a.i. ha⁻¹ Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo-plus at 2.8 (1.8 Propanil +1.0 2,4-D) kg a.i. ha⁻¹ Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo-plus 4.5 (2.88 Propanil +1.6 2,4-D) kg a.i. ha⁻¹

Butachlor at 1.0 kg a.i. ha⁻¹ fb Rainbow at 0.025 (Penoxsulam) kg a.i. ha⁻¹

Butachlor at 1.0 kg a.i. ha⁻¹ fb Rainbow at 0.030 (Penoxsulam) kg a.i. ha⁻¹

Butachlor at 1.5 kg a.i. ha⁻¹ fb Rainbow at 0.025 (Penoxsulam) kg a.i. ha⁻¹

Butachlor at 1.5 kg a.i. ha⁻¹ fb Rainbow at 0.030 (Penoxsulam) kg a.i. ha⁻¹

Butachlor at 1.0 kg a.i. ha^{-1} fb Solito at 0.320 (Pretilachlor 0.30 + Pyribenzoxim 0.02) kg a.i. ha^{-1}

Butachlor at 1.0 kg a.i. ha⁻¹ fb Solito at 0.480 (Pretilachlor 0.45 + Pyribenzoxim 0.03) kg a.i. ha⁻¹

Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.320 (Pretilachlor 0.30 + Pyribenzoxim 0.02) kg a.i. ha⁻¹

Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.480 (Pretilachlor 0.45 + Pyribenzoxim 0.03) kg a.i. ha⁻¹

Butachlor at 1.0 kg a.i ha⁻¹ fb SHW at 4 WAS

Butachlor at 1.0 kg a.i ha⁻¹ fb SHW at 8 WAS

Butachlor at 1.5 kg a.i ha⁻¹ fb SHW at 4 WAS

Butachlor at 1.5 kg a.i ha⁻¹ fb SHW at 8 WAS

Butachlor at 1.0 kg a.i ha⁻¹ fb SHW at 4 & 8 WAS

Butachlor at 1.5 kg a.i ha⁻¹ fb SHW at 4 & 8 WAS

HWC at 2, 4, 6 & 8 WAS

Weedy check

Key:

fb =followed by

SHW = Supplementary hoe weeding

WAS = Weeks after sowing

HWC = Hoe weeded control

3.5 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 *Oryza 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 (Gridely *et al.*, 2002). The seed was supplied by Greenspore Agric. Nigeria Ltd.

3.6 CULTURAL PRACTICES FOR EXPERIMENT I

3.6.1 Land Preparation

The land was cleared, ploughed and harrowed twice to get fine soil tilth and the plots were demarcated according to the dimension stated below. The gross size of the plot was 3x3m while the net plot was 2.2 x 2.2 m. However, a discard of 1meter and 50 cm was provided between the blocks and individual plots, respectively, to avoid chemical contamination and facilitate easy passage for both the experiments. There was a total of 10 plots on each of the replications.

3.6.2 Seed Treatment

The seed was treated with Apron Plus (Hexaconazole 2.g imidacloprid 0.6 g and fenthion 1.2 g) at the rate of 10 g for every 2.5 kg of seed to avoid damage by pest, insects and soil borne diseases.

3.6.3 Sowing

The treated seeds were sown directly into the respective plots. Drilling method was used in sowing the seeds. The spacing was 20 cm between rows using the seed rate of 60 kg per hectare.

3.6.4 Weed Control

This was done by the use of hoe and hand pulling to remove the weeds at their respective time as specified in the treatments schedule.

3.6.5 Fertilizer Application

Fertilizer was applied at the rate of 70 - 30 - 30 kg ha⁻¹ N, P₂O₅ and K₂O, respectively. The 30 kg N and whole of P₂O₅ and K₂O were applied basally using NPK 15-15-15 while second half of N (40 kg) was split into two and applied at 4 and 8 WAS using urea (46% N). The method for fertilizer application was by drilling.

3.6.6 Harvesting

This was done at physiological maturity stage by cutting the panicles from the net plot in each of the plots, threshed and winnowed to get the grains. The respective grain yields from the net plots were packed in a well labeled enveloped for further data collection.

3.7 CULTURAL PRACTICES FOR EXPERIMENT II

3.7.1 Land Preparation

The land was cleared, ploughed and harrowed twice to get fine soil tilth and the plots were demarcated according to the dimension stated below. The gross size of the plot was 3x3m while the net plot was 2.2 x 2.2 m. However, a discard of 1meter and 50cm was provided between the blocks and individual plots, respectively, to avoid chemical contamination and facilitate easy passage for both experiments. There was a total of 20 plots on each of the blocks.

3.7.2 Seed Treatment

The seed was treated with Apron Plus (Hexaconazole 2.g imidacloprid 0.6 g and fenthion1.2g) at the rate of 10 g for every 2.5 kg of seeds to avoid damage by pests, insects and soil borne diseases.

3.7.3 Sowing

The treated seeds were sown directly into the respective plots. Drilling method was used in sowing the seed. The spacing was 20 cm between rows using the seed rate of 60 kg per hectare.

3.7.4 Weed Control

This was done as per the treatments. Pre-emergence (Butachlor) herbicide application was done a day after sowing, while post emergent application was done at 4 WAS. The herbicide was applied by the use of CP3 knapsack sprayer fitted with green deflector nozzle at a pressure of 2.1kg/cm² using discharge volume of 200 L/ ha.

3.7.5 Fertilizer Application

Fertilizer was applied at the rate of 70 - 30 - 30 kgha-¹ N, P_2O_5 and K_2O , respectively. The 30 kg N and whole of P_2O_5 and K_2O were applied basally using NPK 15-15-15 while second half of N (40 kg) was split into two and applied at 4 and 8 WAS by using urea (46% N). The fertilizer was applied by drilling method.

3.7.6 Harvesting

This was done at physiological maturity stage by cutting the panicles from the net plot in each of the plots, threshed with stick and winnowed in air to get the grains. The respective grain yields from the plots were packed in a well labeled enveloped for further data collection.

_3.8 DATA COLLECTION

The procedures in taking data for both experiments I and II were the same as it is stated below:-

There were 15 inter-rows spaced at 20 cm in each plot and out of this the 1^{st} and 15^{th} rows were considered as border while the 2^{nd} and the 14^{th} rows were used as sampling rows. Five plants from each plot were tagged manually within the sampling row for data collection. The inner $3^{rd} - 13^{th}$ rows were used as net plot for yield assessment.

3.8.1 Weed Parameters

Weed species and phytosociological characters

Weeds were harvested from the 1m² 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) and consultation with weed scientists at the Agronomy Department of Bayero University Kano. The weeds were counted to get the number of individual species which was used to compute the weed abundance, frequency, density, relative abundance, relative frequency, relative density and importance value index as described by Das (2011) in the formula below.

Weed cover score

The weed cover score was taken by determining the population of the weed species in each of the treatment plots through visual observation. A scale of 1-9 was assigned, where 1 represented total absence of weed and 9 represented plots completely covered by weeds.

Weed dry weight per plot (g)

This was done by oven drying the weeds identified above to a constant weight at a temperature of 70 0 C for 48 hours.

Weed control efficiency (WCE) (%)

This was done by substituiting the data generated from the above weed dry weights

for the respective treatments to compute the WCE by the use of the equation below:

WCE = Weed dry weight in weedy check - weed dry weight of treatment in question X 100

Weed dry weight in weedy check

Weed density

It expresses the numerical strength of a weed species in a plant community, it is a

measure of the number of individuals per unit area in a community:

Density =

Total number of individual of a species in all the quadrants

(Total number of quadrants studied) x (area in a m^2 of a quadrant)

Weed frequency

It refers to the degree of uniformity of occurrence or dispersion of a species of plant

in an area and represents a number of sampling units in which that species occurred:

Frequency =

Number of quadrants in which species occurred

Total number of quadrants studied

Weed abundance

This refers to the number of individuals of different species in a community based on

the quadrants where they only occurred. This is useful in estimating the dominance of a

species:

Abundance: (A) =

Total number of individuals of a species in all the quadrant

Number of quadrants in which the species occurred

Relative density (RD) %

It measures the numerical strength of a species of a plant in an area in relation to total

number of individuals of all species in a community:

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Relative frequency (RF) %

It measures the degree of uniformity of occurrence or dispersion of a species of plant in an area in relation to total occurrence of individuals of all species:

Relative abundance (RA) %

This measures the dominance of a species of a plant in an area in relation to total dominance of individuals of all species in a community:

Importance value index (IVI)

Describes which species are the most important within the study area:

3.8.2 Crop Growth Parameters

Establishment count (%)

This was done at 14 DAE by counting the number of germinated seedling per unit area (1m quadrant) and compared with the number of seeds planted and multiplied by 100 to get percentage emergence. The area used for taking the establishment count (EC) was demarcated and marked for further data taking on growth and yield attributes.

Plant height (cm)

This was taken by the use of meter rule from the ground level to the top most leaf of 5 randomly selected plants and tagged at 4 and 8 WAS.

Crop vigor score

This was done by visual assessment in each of the plots where plant height, number of leaves and greenness were considered at 4 and 8 WAS. A score of 1-9 was used, where 1 represented totally distorted crop and 9 represented most healthy and vigorous crop. The allocated score for plant height = 4, number of leaves = 4, greenness = 2.

Leaf area (LA) (cm²)

This was done by taking 5 randomly selected plants from the sampling row in each plots and their area was determined by the use of leaf area meter YMJ/Amodel 1. The leaf area determined was divided by 5 to get the mean area per plant.

Leaf area index (LAI)

This was calculated by dividing the LA per plant above with the ground area per plant:

$$LAI = LA/GA$$

Total dry matter per plant (g)

This was taken by cutting 5 plants at random at the height of 2cm above the ground during 4 and 8 WAS and oven dried at 70°C to a constant weight.

Crop growth rate (g/m²/wk)

This is the dry matter accumulation of the crop per unit area per time. It was computed by substituiting the above total dry matter using the formula below.

$$CGR = (W_2-W_1) / (T_2-T_1)$$

Where, T_1 is the day of starting; T_2 is the day of final count; W_1 is the dry weight at T_1 and W_2 is the dry weight at T_2 .

3.9.3 Yield and Yield Components

Number of Panicles per meter square

This was determined from the earlier demarcated area (1m²) by counting the total number of panicles in each plot at harvest.

Panicle length per plant (cm)

This was taken by measuring the length of the grain bearing panicles in each of the 10 randomly tagged plants in the plots with meter rule.

Number of grains per panicle

This data was taken by counting the number of grain for each of the panicles above, and their number was divided by 10 to get the mean panicle number per plant.

Weight of panicles per plant (g)

This was obtained from the sampled paniclesthat were weighed with sensitive balance and the weight obtained were divided by 10 to get the mean weight of the panicles per plant.

1000 - Grain weight (g)

After threshing and winnowing of each of the paddy grain from the net plots, 1000 grains were counted and weighed by the use of mettle digital balance Model 1210 to get their weight.

Paddy yield (kg ha⁻¹)

This was obtained by threshing the panicles from the net plot and winnowed in the air to get a refined grain. The yield obtained from the net plot was converted to per hectare basis in kilogram. The yield was adjusted to 10 % seed moisture content.

Stover yield (kg ha⁻¹)

The stover obtained from each of the plots after harvesting the grain were sun dried and weighed, the weight obtained was converted to per hectare basis in kilogram.

Harvest index (HI %)

This was estimated by dividing the paddy yield with the biological yield and multiplied by 100 to get percentage for each of the plots by using the formula below

$$HI = \frac{\text{Paddy yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})} \times 100$$

NB:

- > Paddy yield is the weight of the clean paddy yield after harvesting in kilogram per hectare
- ➤ Biological yield is the weight of both the paddy and the stover yield taken after sun drying before threshing in kilogram.

Determination of 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 (R²) 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 as:

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

3.9 DATA ANALYSIS

3.9.1 Data Analysis for Experiment I and II

Data collected were subjected to analysis of variance using the general linear model in SAS (SAS, 2004). Where significant, the treatments means were separated by using Student-Newman-Keuls test (SNK). Simple correlation and path coefficient analysis was run to determine the relationship among some important growth, yield and weed parameters as described by Little and Hill (1978). The direct and indirect effects of individual and combined contributions of some selected characters to paddy yield were determined using path coefficient analysis as described by Dewey and Liu (1959).

Cost-benefit analysis (Experiment I & II)

An economic assessment was done to determine the production cost, revenue and the gross margin that was derived from each of the treatments. The cost of all inputs was recorded along with the price of the produce at the farm gate price. The gross margin (GM) was obtained by subtracting the total variable cost (TVC) of production from the total revenue (TR) (Olukosi and Erhabor, 1988). The profitability index, also known as cost-benefits analysis measures the rate of return on investment and gives the amount of profit on every Naira invested in each of the weed interference periods and control methods. It is expressed as GM=TR-TVC, where Cost-benefit ratio (C:B) = TR/TVC,

GM = Gross margin, TR = total revenue and TVC = total variable cost of each of the weed interference periods and control methods.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Weather Parameters of the Expiremental Sites

Weather data on rainfall, minimum and maximum tempurature of BUK and DBT for 2016 and 2017 raining seasons is presented in Appendices I, II & III.. The total amount of rainfall received was 863 mm and 934 mm for BUK and DBT, respectively in 2016 and 820 mm and 892 mm for the respective locations in 2017 raining season. It indicated moderate rainfall at both sites. However, the rainfall was relatively higher in 2016 compared with that of 2017 at both locations, similarly rainfall records at DBT was slightly higher than in its BUK counterpart at both seasons. The record also indicated uneven rainfall distribution where the peak rainfall occurred in the last (Appendix I) ten days of May and mid of June at BUK and DBT respectively, in 2016 raining season. The highest rainfall was received in the first ten days of June at DBT, while high but stable rainfall was recorded at BUK from the mid of July up to the last ten days of August in 2017 raining season. The record also signified the rainfall to be more extended up to the last ten days of October at BUK in 2017 raining season. The minimum and maximum tempurature were very high at the beginning of the raining seasons at both locations (Appendix 1). The temperature was however, gradually decreased as the amount of rainfall was increasing up to the month of August where it sponteneously increased as a result of decreased volume of rainfall received toward the end of the raining season. Minimum and maximum Temperatures were slightly higher at DBT compared to those of BUK in both seasons (Appendix 1).

4.1.2 Soil Physical and Chemical Characteristics of the Experimental Sites

Soil physical and chemical properties of BUK and DBT during 2016 and 2017 raining seasons are presented in Table 1. It could be observed that the soil was sandy loam and loamy sand for BUK and DBT, respectively, during both years. The soil pH was slightly (6.52 – 6.79) acidic at both locations and seasons. Total nitrogen content was generally low; very low organic carbon and high available P was also observed at both locations and growing seasons. It also indicated moderate potassium and calcium content and low cation exchange capacity (CEC). (Science Society of Nigeria, Soil fertility status rating 2014).

Table 1: Soil Physical and Chemical Charestiristics of BUK and DBT Locations during 2016 and 2017 Raining Seasons

| Soil properties | 20 | 16 | 2017 | | |
|--------------------------------------|-------------------|------------|------------|------------|--|
| | BUK | DBT | BUK | DBT | |
| Physical Properties (%) | | | | | |
| Clay | 12.4 | 15.1 | 12.7 | 15.8 | |
| Silt | 22.3 | 20.3 | 21.3 | 21.0 | |
| Sand | 65.4 | 64.6 | 66.0 | 63.2 | |
| Textural Class | Sandy loam | Loamy sand | Sandy loam | Loamy sand | |
| Chemical properties | | | | | |
| рH (H ₂ O) | 6.79 | 6.52 | 6.54 | 6.70 | |
| Organic Carbon (g kg ⁻¹) | 2.71 | 2.91 | 2.97 | 2.75 | |
| Гotal N (g kg ⁻¹) | 0.65 | 0.53 | 0.69 | 0.57 | |
| Available P (mg kg ⁻¹) | 22.0 | 21.4 | 22.2 | 21.8 | |
| Exchangeable Cations (cmol kg | g ⁻¹) | | | | |
| Ca | 2.15 | 2.31 | 2.34 | 2.20 | |
| Mg | 1.11 | 0.93 | 1.04 | 1.19 | |
| ζ | 0.30 | 0.32 | 0.36 | 0.35 | |
| Na | 0.14 | 0.19 | 0.15 | 0.24 | |
| CEC | 7.43 | 7.31 | 7.15 | 7.25 | |

Analysed at Soil Science Laboratory of Bayero Unuversity Kano

BUK = Bayero University Kano DBT = Audu Bako College of Agriculture Dambatta

4.1.3 Results for Weed Interference

Weed species composition

Weed species composition of the experimental sites is presented in Table 2. There were a total of eighteen (18) weed species identified at BUK in 2016. Six were grasses, eight were broad leaved and four were sedges. Rottboellia cochinchinensis (Lour.) Clayton had the highest relative frequency 0f 18.5% followed by I. asarifolia (Desr.) Roem. (13.1%) while the least relative frequency was recorded by Oryza longistaminata (A.) Chev. (1.5%). There were a total of fifteen (15) weed species identified at DBT in 2016. Seven were broad leaved; grasses and sedges were four each. Fimbristylis ferruginea (L.) Vahl had the highest relative frequency 0f 8.5% while the least figure was recorded by *Oryza longistaminata* (A.) Chev. (2.5%). In 2017 similarly a total of 16 weed species were identified at BUK where Rottboellia cochinchinensis (Lour.) Clayton had the highest relative frequency (18.2) and was followed by Tridax procumbens (L.) with 14.1%, while Commelina benghalensis (L.) and Panicum maximum (Jacq) had the least figure with 2% each. There were a total of sixteen (16) weed species also identified at DBT in 2017. Seven were broad leaved; while four and five grasses and sedges were identified respectively. Cyperus esculantus (L.) had the highest relative frequency 0f 10.0% while the least figure was recorded by Ageratum convioles (L.) (2.5%)

Table 2: Weed species composition at BUK and DBT in 2016 and 2017 raining seasons

| | 2016 | | _ | | 2017 | | |
|------------------------------------|---------------------|------|----------|---------------------------------------|---------------------|---------------|------|
| | | | ency (%) | | | Frequency (%) | |
| | Common name | BUK | DBT | Weed species | Common name | BUK | DBT |
| Grasses | | | | Grasses | | | |
| R. cochinchinensis (Lour.) Clayton | Itch grass | 18.5 | - | R. cochinchinensis (Lour.) Clayton | Itch grass | 18.2 | - |
| I. cylindrica (L.) Raeuschel | Spear grass | 3.0 | - | I. cylindrica (L.) Raeuschel | Spear grass | 3.0 | - |
| P. maximum Jacq | Guinea grass | 2.0 | 7.4 | P. maximum Jacq | Guinea grass | 2.0 | 7.4 |
| D. horizontalis Willd | Crab grass | 3.0 | 7.7 | D. horizontalis Willd | Crab grass | 3.0 | 7.7 |
| C. dactylon (L) Pers. | Bahama grass | 8.1 | 8.1 | C. dactylon (L) Pers. | Bahama grass | 8.1 | 8.1 |
| E. indica (Gaertn.) | Goosegrass | 2.0 | 6.4 | E. indica (Gaertn.) | Goosegrass | 5.0 | 6.4 |
| O. longistminata (A) Chev. | Wild rice | 1.2 | 2.1 | O. longistminata (A) Chev. | | | |
| Broad leaved | | | | Broad leaved | | | |
| I. asarifolia (Desr.) Roem. | water spinach | 13.1 | 7.2 | I. asarifolia (Desr.) Roem. | Water spinach | 13.1 | 7.2 |
| S. occidentalis (L.) Link | Coffee senna | 5.0 | 8.3 | S. occidentalis (L.) Link | Coffee senna | 5.0 | 8.3 |
| A. spinosus (L). | spiny amaranth | 4.0 | 5.5 | A. spinosus (L). | Spiny amaranth | 4.0 | 3.0 |
| A. hispidum (DC). | Star burr grass | - | 8.3 | A. hispidum (DC). | Star burr grass | - | 8.3 |
| T. procumbens (L.) | coat buttons | 14.1 | 6.9 | T. procumbens (L.) | Coat buttons | 14.1 | 6.9 |
| P. amarus (Schum.&Thon). | | 9.1 | 6.8 | P. amarus (Schum.&Thon). | | 9.1 | 6.8 |
| C. retusa (L.) | Rattlebox | _ | 8.1 | C. retusa (L.) | Rattlebox | - | 8.1 |
| C. benghalensis (L.) | Tropical spiderwort | 2.0 | - | C. benghalensis (L.) | Tropical spiderwort | 2.0 | - |
| Sedges | | | | Sedges | | | |
| L. hexandra (Sw.) | Cut grass | 2.0 | - | L. hexandra (Sw.) | Cut grass | 2.0 | - |
| C. esculentus (L) | Yellow nut sedge | 7.3 | 7.9 | C. esculentus (L) | Yellow nut sedge | 7.3 | 10.0 |
| K. squamulata (Thonn.) | | 3.0 | 7.2 | K. squamulata (Thonn.) | | 3.0 | 7.2 |
| F. ferruginea (L.) Vahl | | 3.0 | 8.5 | F. ferruginea (L.) Vahl | | 3.0 | 5.5 |
| , , | | | | L. martinisensis (L) | Wild tea bush | _ | 3.5 |
| A. aspera (L) | devil's horsewhip | 1.5 | | A. aspera (L) | Goat weed | | 2.5 |

Establishment count at 14 DAE (%)

The effect of period of weed interference on establishment count of rice at Bayero University Kano (BUK) and Audu bako College of Agriculture Dambatta (DBT) research farms during 2016 and 2017 raining seasons is presented in Table 3. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons, except at DBT in 2016. The statistically highest establishment count at BUK in 2016 was recorded by WIF at 28 DAE but was at par with WIF at 42 and WIF at 56 DAE. However, at both sites in 2017, the highest establishment count was from WF until harvest though it was at par with all other treatments except WIF until harvest and WF at 14 DAE which recorded the significantly lowest mean at BUK while at DBT only WIF until harvest had the lowest record.

Table 3: Establishment Count (%) of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Periof of Weed interference | | | | | | | |
|-----------------------------|----------------------------|------------|------------|------------|--|--|--|
| | 20 | 16 | 2017 | , - | | | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | | | |
| Weed free period (W | F) | | | | | | |
| 14 DAE | 42.4bcd | 75.8 | 41.6b | 53.9ab | | | |
| 28 DAE | 38.4cd | 78.5 | 48.8ab | 44.4ab | | | |
| 42 DAE | 46.6bcd | 80.3 | 48.9ab | 46.1ab | | | |
| 56 DAE | 36.0d | 76.3 | 56.1ab | 54.8ab | | | |
| Until harvest | 52.5bcd | 79.3 | 69.0a | 62.4a | | | |
| Weed infested period | Weed infested period (WIF) | | | | | | |
| 14 DAE | 63.8bcd | 70.5 | 46.4ab | 43.6ab | | | |
| 28 DAE | 83.4a | 62.5 | 50.0ab | 40.8bb | | | |
| 42 DAE | 67.0ab | 56.6 | 39.1b | 54.4ab | | | |
| 56 DAE | 66.0ab | 71.5 | 55.3ab | 42.3ab | | | |
| Until harvest | 55.5bcd | 61.0 | 53.5ab | 40.0b | | | |
| SE ± | 15.9 | 19.4 | 14.3 | 12.3 | | | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, CGR – Crop growth rate

Plant height

The effect of period of weed interference on plant height of rice at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 4. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons, except at 56 DAE in 2017 at both locations. The tallest plants at BUK in 2016 raining season during 28 DAE were recorded by WF at 56 DAE, but it was at par with the entire weed free and WIF at 14 DAE. The shortest plants were produced by the WIF until harvest which was at par with WIF at 42 DAE. At DBT in the same period and year (2016) however, the tallest plants were produced by WF at 28 DAE though at par with all other treatments except WIF at 56 DAE and WIF until harvest. During 56 DAE sampling period in 2016 growing season, all other treatments gave comparable taller plants than WIF at harvest. . At DBT in the corresponding period the tallest plants was produced by the same treatment (WF until harvest) but was at par with WF at 14, WF at 28 and WF at 56 DAE while other treatments were statistically similar to the WIF until harvest which produced the shortest plant. In 2017 at both locations during 28 DAE, all the treatments were at par except the WIF until harvest which had the shortest plants. .

Table 4: Plant Height of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference per | riod | | | | | | | | |
|-----------------------|------------|-----------------------|------------|-----------------------|------------|-----------------------|------------|--------------|--|
| | | 2016 | | | | 2017 | | | |
| | P/height @ | P/height @ 28DAE (cm) | | P/height @ 56DAE (cm) | | P/height @ 28DAE (cm) | | @ 56DAE (cm) | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | |
| Weed free period (| (WF) | | | | | | | | |
| 14 DAE | 39.0ab | 47.5ab | 74.3a | 66.5abc | 57.8a | 30.5a | 69.8 | 45.3 | |
| 28 DAE | 38.8ab | 53.3a | 69.0a | 68.3ab | 50.8a | 29.5a | 75.8 | 52.8 | |
| 42 DAE | 40.5ab | 48.5ab | 65.5a | 55.5bc | 58.0a | 26.5ab | 72.5 | 46.0 | |
| 56 DAE | 43.3a | 49.3ab | 72.3a | 65.5abc | 51.0ab | 31.8a | 74.3 | 53.5 | |
| Until harvest | 38.8ab | 47.5ab | 77.3a | 72.8a | 55.0ab | 30.5a | 74.5 | 55.0 | |
| Weed infested per | iod (WIF) | | | | | | | | |
| 14 DAE | 37.8ab | 45.3ab | 70.3a | 54.3c | 50.3ab | 27.8a | 73.3 | 49.5 | |
| 28 DAE | 36.8b | 45.8ab | 69.3a | 57.0bc | 50.5ab | 27.0a | 70.0 | 50.3 | |
| 42 DAE | 35.3bc | 46.8ab | 63.0a | 57.3bc | 46.0ab | 28.5a | 71.3 | 45.8 | |
| 56 DAE | 36.3b | 41.3bc | 67.3a | 57.8bc | 53.5ab | 27.8a | 71.5 | 50.0 | |
| Until harvest | 30.5c | 37.8c | 45.8b | 53.5c | 44.3b | 22.0b | 57.5 | 40.0 | |
| SE ± | 3.77 | 5.62 | 9.88 | 8.07 | 7.62 | 3.24 | 11.1 | 9.00 | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, P/height – plant height

Number Tillers per meter square

The effect of period of weed interference on number of tillers per meter square at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 5. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons. The highest number of tillers at both locatios in 2016 during 28 DAE was produced by the WF at 56 DAE, but was at par with WF until harvest, WF at 14 DAE and WIF at 42 DAE at BUK and the entire treatments at DBT except The WIF harvest which had the lowest number. The highest number of tillers were recorded by WF until harvest at BUK during 56 DAE sampling period but was similar with all the treatments except the WIF until harvest which was significantly lower. At DBT in the same period the treatment recorded the highest number but was at par with WF at 14, WF at 42 and WF until harvest while the statistically lowest number was obtained from WIF harvest. In 2017, record indicated the highest number of tillers observed from the WF until harvest though it was at par with WF at 14 and WF at 42 DAE at BUK during 28 DAE. But at DBT in the corresponding period the WF until harvest was at par with all the treatments except WIF until harvest which had the significantly lowest number. Similarly, the WF until harvest during 56 DAE sampling period recorded the significantly highest number of tillers at BUK but it was at par with all the treatments except WIF until harvest which had the lowest figure. At DBT in the period this same treatment was at par with all the treatments except the WIF until harvest which had the least number

Table 5: Number Tillers per Meter Square of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference period | | | | | | | | | |
|--------------------------|---------------|-------------------------------------|------------|------------------------------------|------------|------------------------------------|------------|------------------------------------|--|
| | | 2016 | | | | 2017 | | | |
| | Tillers per m | Fillers per m ⁻² @ 28DAE | | Tillers per m ⁻² @56DAE | | Tillers per m ⁻² @28DAE | | Tillers per m ⁻² @56DAE | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | |
| Weed free period | d (WF) | | | | | | | | |
| 14 DAE | 98.5abc | 87.8ab | 171.3a | 151.3ab | 108.3ab | 87.3a | 174.5ab | 152.5a | |
| 28 DAE | 88.5bc | 64.3ab | 140.5ab | 116.3bc | 105.0b | 90.5a | 178.0ab | 128.3a | |
| 42 DAE | 88.5bc | 83.0ab | 159.3a | 138.0ab | 118.0ab | 97.5a | 196.0a | 152.3a | |
| 56 DAE | 115a | 100.3a | 182.0a | 180.0a | 94.5bc | 93.8a | 139.8ab | 132.5a | |
| Until harvest | 87ab | 91.0ab | 182.5a | 151.5ab | 137.5a | 114.3a | 196.8a | 175.0a | |
| Weed infested p | eriod (WIF) | | | | | | | | |
| 14 DAE | 88.5bc | 80.5ab | 159.0a | 119.8bc | 102.8bc | 95.8a | 179.3ab | 103.5ab | |
| 28 DAE | 87.8bc | 56.8b | 151.0a | 77.5cd | 101.0bc | 85.5a | 169.8ab | 135.5a | |
| 42 DAE | 82.0abc | 74.5ab | 176.8a | 107.5bc | 99.3bc | 83.5a | 189.9a | 136.8a | |
| 56 DAE | 88.8bc | 81.3ab | 153.0a | 120.3bc | 95.3bc | 88.3a | 169.0ab | 126.8a | |
| Until harvest | 64.0cd | 24.5c | 104.0b | 32.0d | 73.0c | 47.5b | 117.5b | 49.5b | |
| SE ± | 13.5 | 20.7 | 29.6 | 34.0 | 18.7 | 21.5 | 37.8 | 43.7 | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – days after emergence BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Crop Vigor Score

The effect of period of weed interference on crop vigor score of rice at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 6. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons on crop vigor score except at DBT in 2016 during 56 DAE where no significant difference was observed. All other treatments resulted in statistically similar or comparable crop vigor score of rice that was significantly higher than that of weed infested until harvest at BUK during 28 DAE sampling in 2016 wet season. Similar trend was observed at DBT in the same period except that the lowest score by WIF until harvest was at par with WF at 14, WIF at 28 and WIF at 56 DAE as indicated in Table 6. Crop vigor score record at 56 DAE sampling period in 2016 was only significant at BUK, where WF until harvest and WIF at 28 DAE where the highest but statistically similar with all the treatments except the WIF until harvest and WIF 52 DAE which had the lowest figure. Recorded data at both locations in 2017 indicated the crop vigor score to be significantly different ($P \le 0.05$) with WF until harvest having the highest score in all the locations and sampling periods except at BUK where WIF at 56 had the highest score but is still at par with the WF until harvest, WIF at 28 and WIF at 42 DAE. The statistically lowest score was produced by the WIF until harvest at both locations.

Table 6: Crop Vigor Score of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| | | 20 | 16 | | | 20 | 17 | |
|------------------|------------------|------------|---------------|------------|---------------|-------------|---------------|-------------|
| | Crop vigor score | e @28DAE | Crop vigor sc | ore @56DAE | Crop vigor se | core @28DAE | Crop vigor so | core @56DAE |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> |
| Weed free period | (WF) | | | | | | | |
| 14 DAE | 6.0a | 4.3a-e | 6.0ab | 3.25 | 4.5cde | 5.8ab | 4.3bc | 6.8bc |
| 28 DAE | 7.0a | 5.8abc | 5.8ab | 4.00 | 3.5de | 5.5ab | 4.0bc | 6.5ab |
| 42 DAE | 6.5a | 6.50ab | 4.8abc | 4.50 | 2.5e | 6.3ab | 2.8bc | 6.8ab |
| 56 DAE | 7.5a | 6.80a | 5.0abc | 4.30 | 2.75e | 6.5ab | 3.5bc | 6.5ab |
| Until harvest | 7.5a | 7.30a | 6.8a | 4.75 | 6.25abc | 8.0a | 7.3a | 7.8a |
| Weed infested pe | riod (WIF) | | | | | | | |
| 14 DAE | 7.8a | 5.30a-d | 4.5abc | 3.75 | 3.75de | 6.3ab | 5.3ab | 4.8c |
| 28 DAE | 7.3a | 3.00de | 6.8a | 3.00 | 5.0abc | 5.3b | 2.3c | 4.0c |
| 42 DAE | 6.5a | 5.50abc | 6.0ab | 4.75 | 6.5ab | 6.0ab | 2.5c | 4.8c |
| 56 DAE | 6.3a | 4.00cde | 4.0bc | 3.75 | 7.75a | 5.5ab | 5.3ab | 4.5c |
| Until harvest | 4.0b | 2.50e | 3.0bc | 2.00 | 2.5e | 3.0c | 1.8c | 2.0d |
| SE ± | 1.31 | 1.49 | 1.32 | 2.23 | 1.26 | 1.52 | 1.64 | 1.10 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta,

CVS = Using a scale of 1-9 where 1 represented completely dead plants and 9 represented the most vigorous plants.

Leaf area

The effect of period of weed interference on leaf area at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 7. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons on leaf area. The largest leaf area was recorded by WIF at 14 DAE at BUK in 2016 though it was at par with all the treatments except WF at 42, WF at 56 and WIF until harvest which had the smallest area. Result from DBT in 2016 indicated WF until harvest to have largest leaf area but was only statistically higher than WF at 14, WIF at 28, WIF at 56 and WIF until harvest. Data recorded at BUK in 2017 indicated the largest leaf area to be scored by WF until harvest but was at par with all the treatments except the WIF until harvest which had smaller leaf area. The WF until harvest which had the largest leaf was only at par with WF at 28 and WIF at 14 DAE while the smallest leaf area was produced by WIF until harvest.

Leaf area index

The effect of period of weed interference on leaf area index (LAI) at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 7. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons on LAI. The highest LAI was recorded by WF until harvest at both locations, but was at par with all the treatments exceptWF at 42, WIF at 28 and WIF until harvest at BUK. But at DBT it was at par with all the treatments except the WIF at 28 and WIF until harvest which significantly had lowest LAI at both locations in 2016. Result in 2017 indicated that, WIF at 14 DAE and WF at 42 DAE to produce the highest LAI at BUK and WF until harvest at DBT, but it was at par with all the

treatments except WIF until harvest at BUK and with WF at 14, WF at 28 and WIF at 28 DAE at DBT. Similarly the lowest LAI was recorded by WIF until harvest at both locations in that year.

Crop growth rate (CGR)

The effect of period ofweed interference on crop growth rate (CGR) at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 8. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons. The statistically highest CGR were recorded by WF until harvest at both locations and growing seasons except at DBT in 2017 where WF at 42 DAE recorded the highest CGR. This best treatment (WF until harvest) was at par with all the treatments except WF at 14 DAE, WF at 28 DAE, WF at 42 DAE and the WIF until harvest at BUK and except WIF at 28 DAE and WIF until harvest at DBT in 2016. Similarly, in 2017 WF until harvest recorded the highest CGR but was at par with WF at 56 DAE, WIF at 28 DAE and WIF at 56 DAE at BUK. But at DBT in the same year however, the highest CGR was produced by WF at 42 DAE but was at par with all the treatment except WF at 56 DAE and the WIF until harvest.

Table 7: Leaf Area and Leaf Area Index of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference | period | | | | | | | | | |
|----------------------|------------|--------------------|------------|------------|------------|----------------------|------------|--------------|--|--|
| | | 201 | 6 | | 2017 | | | | | |
| | Leaf area | (cm ²) | Leaf are | a index | Leaf area | a (cm ²) | Leaf area | <u>index</u> | | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | | |
| Weed free period (\ | WF) | | | | | | | | | |
| 14 DAE | 28.5ab | 18.9b | 2.9ab | 0.74abc | 29.7ab | 21.5bc | 3.11ab | 1.12abc | | |
| 28 DAE | 28.6ab | 22.6ab | 2.7abc | 1.0abc | 23.7ab | 24.9ab | 2.75ab | 1.31ab | | |
| 42 DAE | 21.3bc | 22.9ab | 2.2bc | 1.03ab | 29.6ab | 19.90bc | 3.50a | 0.97bc | | |
| 56 DAE | 28.7bc | 20.9ab | 2.8ab | 1.14ab | 32.0ab | 20.9bc | 2.82ab | 0.70bc | | |
| Until harvest | 30.0ab | 25.1a | 3.8a | 1.25a | 34.8a | 28.0a | 3.38ab | 1.78a | | |
| Weed infested period | od (WIF) | | | | | | | | | |
| 14 DAE | 35.4a | 22.7ab | 3.3ab | 0.81abc | 33.4ab | 25.0ab | 3.60a | 0.96bc | | |
| 28 DAE | 29.5ab | 17.7b | 2.6bc | 0.42bc | 34.5a | 23.0b | 3.32ab | 1.10ab | | |
| 42 DAE | 30.2ab | 20.3ab | 3.0ab | 0.71abc | 30.9ab | 19.93bc | 3.24ab | 0.82b | | |
| 56 DAE | 31.4ab | 18.1b | 2.9ab | 0.50abc | 30.7ab | 19.89bc | 2.97ab | 0.89bc | | |
| Until harvest | 19.9c | 17.7b | 1.7c | 0.18c | 20.9b | 17.63c | 2.01b | 0.46c | | |
| SE ± | 5.59 | 4.60 | 0.68 | 0.46 | 7.74 | 4.10 | 0.86 | 0.48 | | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK , DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Table 8: Crop Growth Rate (g/m²/wk) of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference per | iod <u>2</u> | 016 | 2 | 017 | |
|-----------------------|--------------|------------|------------|------------|--|
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | |
| Weed free period (W | F) | | | | |
| 14 DAE | 7.0bc | 4.6ab | 7.7bc | 4.1ab | |
| 28 DAE | 7.7bc | 4.0ab | 9.4bc | 3.8ab | |
| 42 DAE | 7.7bc | 3.9ab | 9.9b | 5.4a | |
| 56 DAE | 9.1ab | 4.3ab | 11.2ab | 2.9b | |
| Until harvest | 11.9a | 5.7a | 15.3a | 4.6ab | |
| Weed infested period | l (WIF) | | | | |
| 14 DAE | 10.5ab | 3.9ab | 9.8b | 3.6ab | |
| 28 DAE | 8.4ab | 2.9b | 9.3ab | 3.8ab | |
| 42 DAE | 10.5ab | 4.3ab | 8.1bc | 4.3ab | |
| 56 DAE | 8.4ab | 3.5ab | 11.5ab | 3.6ab | |
| Until harvest | 4.5c | 2.8b | 4.8c | 2.9b | |
| SE ± | 2.38 | 0.98 | 2.73 | 1.12 | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Dry matter per plant (g)

The effect of period of weed interference on dry matter per plant at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 9. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons. The heaviest DMP was recorded by WF until harvest at all the locations in 2016, except at BUK during 28 DAE where the WIF at 28 DAE was the statistically the heaviest. At BUK in 2016 WIF at 42 DAE resulted in high and comparable dry matter weight per plant of rice than all other treatments but heavier than that of weed infested until harvest at 28 DAE sampling. At DBT however, it was the WF until harvest that gave significantly higher dry matter weight than than weed free at 14 DAE and all weed infested treatments in 2016. In 2017 during 28 DAE, the heaviest DMP was recorded by WF until harvest at BUK and by WF at 28 DAE at DBT but they were only statistically higher than WF at 28, WIF at 14, WIF at 28 DAE and WIF until harvest, and at par with the entire treatments at BUK and DBT respectively. The WIF at 28 DAE and WF until harvest had the statistically heaviest DMP at BUK and DBT respectively, during 56 DAE, though at par with all the treatments except WF at 14, WIF at 42 DAE and WIF until harvest and with all the treatments except WF at 56 DAE and WIF until harvest at BUK and DBT respectively.

Table 9: Dry Matter Weight per Plant of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference | period | | | | | | | | | |
|---------------------|----------------|------------|------------|------------|------------|------------|-----------------|------------|--|--|
| | | 2 | 016 | | 2017 | | | | | |
| | <u>DMP @ 2</u> | 8DAE (g) | DMP @ | 56DAE (g) | DMP @ 28 | DAE (g) | DMP @ 56DAE (g) | | | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | | |
| Weed free period (V | VF) | | | | | | | | | |
| 14 DAE | 8.3ab | 5.5bc | 22.5bc | 14.8abc | 8.5abc | 6.5ab | 22.5bc | 16.0ab | | |
| 28 DAE | 7.0ab | 8.3ab | 22.5bc | 16.5a | 7.3bc | 10.0a | 26.0ab | 16.3ab | | |
| 42 DAE | 5.8ab | 7.0abc | 21.0bc | 14.8abc | 7.8abc | 7.3ab | 27.5ab | 18.0a | | |
| 56 DAE | 6.5ab | 7.5abc | 25.5b | 16.0ab | 10.3ab | 6.5ab | 32.5a | 11.5b | | |
| Until harvest | 7.3ab | 9.8a | 33.8a | 17.8a | 11.5a | 7.5ab | 25.8ab | 18.1a | | |
| Weed infested perio | od (WIF) | | | | | | | | | |
| 14 DAE | 8.3ab | 6.3bc | 28.0ab | 11.3bc | 6.8bc | 7.5ab | 26.3ab | 14.8ab | | |
| 28 DAE | 9.0a | 5.5bc | 26.0b | 14.0abc | 7.0bc | 7.5ab | 33.3a | 15.0ab | | |
| 42 DAE | 7.0ab | 6.3bc | 27.5ab | 15.0abc | 8.5abc | 7.8ab | 22.5bc | 17.5ab | | |
| 56 DAE | 8.0ab | 4.5c | 21.8bc | 11.5bc | 10.0ab | 8.0ab | 33.0a | 15.3ab | | |
| Until harvest | 3.8b | 4.8c | 15.8c | 10.8c | 5.8c | 6.5ab | 16.8c | 11.3b | | |
| SE ± | 2.73 | 1.99 | 4.82 | 2.89 | 2.39 | 2.65 | 5.23 | 3.84 | | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, DMP – dry matter per plant

Panicle weight (g)

The effect of period of weed interference on panicle weight at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 10. Significant differences ($P \le 0.05$) on the effect of weed interference were observed only at BUK in 2016 and DBT in 2017. The heaviest panicle was recorded by WF until harvest and WF at 56 DAE at BUK in 2016, but was at par with all the treatments except the WIF until harvest which had the significantly lightest panicle. In 2017, however, WF until harvest produced the significantly heaviest panicle which was only at par with WIF at 14 DAE at DBT. The lightest panicle was observed in WIF until harvest, though at par with most of the treatments.

Panicle length (cm)

The effect of period of weed interference on panicle length at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 10. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at all the locations and growing seasons except at DBT in 2016. The longest panicles were recorded by WF at 28 DAE, 56 DAE, WF until harvest and also WIF at 14 DAE which were statistically at par with all other treatments except weed infested at harvest which gave the shortest panicles of rice at BUK in 2016. In 2017 raining season the longest panicle was recorded by WIF at 14 DAE at both locations, but was statistically similar with and WF at 56, WIF at 14 DAE and WF until harvest at BUK and with WF at 56 DAE and WF until harvest at DBT. The shortest panicle was recorded by WIF until harvest at all the locations and growing seasons.

Table 10: Panicle Weight and Panicle Length of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference p | eriod | | | | | | | | | |
|---------------------|------------|------------|---------------------|------------|--------------------|------------|---------------------|------------|--|--|
| | | | 2016 | | | 2017 | | | | |
| | Panicle w | eight (g) | Panicle length (cm) | | Panicle weight (g) | | Panicle length (cm) | | | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | | |
| Weed free period (| (WF) | | | | | | | | | |
| 14 DAE | 5.3ab | 3.0 | 20.3ab | 11.5 | 4.8 | 3.8bc | 18.5bc | 14.8bc | | |
| 28 DAE | 4.8ab | 3.5 | 21.3 a | 11.3 | 4.5 | 2.8c | 19.3bc | 13.4c | | |
| 42 DAE | 5.3ab | 3.5 | 20.5ab | 14.5 | 5.3 | 3.0c | 20.0bc | 11.5c | | |
| 56 DAE | 6.8a | 4.0 | 22.3a | 14.0 | 5.5 | 4.0bc | 21.5ab | 19.5ab | | |
| Until harvest | 6.8a | 3.8 | 20.0a | 14.8 | 5.8 | 5.3a | 21.3ab | 17.0abc | | |
| Weed infested perio | od (WIF) | | | | | | | | | |
| 14 DAE | 5.8ab | 3.0 | 22.0a | 11.6 | 5.3 | 4.5ab | 24.3a | 21.0a | | |
| 28 DAE | 5.5ab | 2.8 | 20.5ab | 11.3 | 5.8 | 3.3bc | 21.5ab | 12.3c | | |
| 42 DAE | 5.0ab | 3.3 | 20.5ab | 12.3 | 4.8 | 3.3bc | 18.5bc | 12.8c | | |
| 56 DAE | 5.5ab | 2.8 | 18.3ab | 11.8 | 4.8 | 3.0c | 17.0cd | 13.3c | | |
| Until harvest | 3.3b | 3.0 | 17.0b | 9.8 | 4.0 | 2.8c | 14.3d | 11.5c | | |
| SE ± | 1.6 | 0.9 | 2.4 | 3.6 | 1.2 | 0.8 | 2.0 | 1.4 | | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Number of Panicle per meter square

The effect of period of weed interference on number of panicle per meter square at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 11. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at both locations and growing seasons. In 2016 wet season, the highest number of panicles per meter square was recorded by WF until harvest and WIF at 14 DAE at BUK, but were comparable to all other treatments except WIF until harvest. At DBT however, it were WF at both 42 and 56 DAE that recorded highest number of panicles per m^2 than WIF at 28 DAE and at harvest but were statistically at par with all other treatments. In 2017 similarly, the best treatment (WF until harvest) was at par with all other treatments except the WIF until harvest at BUK, but at DBT it was at par with all the treatments except WIF at 14, WIF at 56 DAE and WIF until harvest which had the least number at both locations.

Table 11: Panicles per Meter Square of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference period | l | | | |
|--------------------------|------------|----------------------------|------------|----------------------------|
| | 2 | 016 | | 2017 |
| | Number o | f Panicles m ⁻² | Number o | f Panicles m ⁻² |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> |
| Weed free period (WF |) | | | |
| 14 DAE | 79.3ab | 49.0ab | 67.3ab | 72.5ab |
| 28 DAE | 61.3ab | 49.8ab | 74.8ab | 64.8abc |
| 42 DAE | 62.8ab | 71.0a | 75.8ab | 52.3a-d |
| 56 DAE | 79.3ab | 78.3a | 70.8ab | 40.5a-d |
| Until harvest | 95.3a | 49.3ab | 104.8a | 74.0a |
| Weed infested period (| WIF) | | | |
| 14 DAE | 100.5a | 47.0ab | 87.0a | 32.8cd |
| 28 DAE | 77.3ab | 18.8bc | 93.5a | 45.0a-d |
| 42 DAE | 82.0ab | 54.8ab | 68.0ab | 39.3a-d |
| 56 DAE | 83.5ab | 48.5ab | 78.5a | 35.3bcd |
| Until harvest | 50.0b | 12.8c | 35.8b | 19.8d |
| SE ± | 26.02 | 22.10 | 25.91 | 22.91 |
| | | | | |

Means with the same letter in the same column are not significantly different ($P \le 0.05$) using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Stover yield (kg ha⁻¹)

The effect of period of weed interference on stover yield at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 12. Significant differences ($P \le 0.05$) on the effect of weed interference were observed at all the locations and growing seasons except at DBT in 2016 raining season. The highest stover yield was recorded by WF until harvest at BUK in 2016 but was statistically the same with all the treatments except WF at 56 and WIF until harvest which had the lowest yield by statistical ranking. In 2017 raining season however, the highest stover yield was produced by WF until harvest though was at par with WIF at 28, WIF at 42, WIF at 56 DAE and WIF until harvest at BUK, while at DBT it was at par with only WF at 28, WF at 56 and WIF at 14 DAE. The lowest stover yield was recorded by WIF until harvest at both locations.

Paddy yield (kg ha⁻¹)

The effect of period of weed interference on the paddy yield of upland rice at BUK and DBT in 2016 and 2017 raining seasons is presented in Table 12. Significant differences ($P \le 0.05$) on paddy yield were recorded at both locations and growing seasons. In 2016 raining season, WF until harvest gave significantly higher paddy yield than all other treatments but was at par with WIF at 14 DAE at BUK while , it was the same with WF until harvest that gave significantly higher paddy yield than all other treatments at DBT in the same season. In 2017 similarly, WF until harvest was at par with WF at 56 and WIF at 14 DAE at BUK while at DBT similar trend with that of 2016 was observed. The WIF until harvest recorded the statistically lowest paddy yield at all

the locations and raining seasons except at DBT in 2017 where it was at par with WIF at 56 DAE.

Harvest index (%)

The effect of period of weed interference on harvest index at BUK and DBT research farms during 2016 and 2017 raining seasons is presented in Table 13. No Significant differences ($P \le 0.05$) on the effect of weed interference on harvest index of rice were observed at both locations and growing seasons except at DBT in 2107 where there were significant differences. The highest harvest index at DBT in 2017 raining season was recorded by the WIF at 28 DAE and WF until harvest but were statistically at par with all the treatments except WF at 28, WIF at 56 DAE and WIF until harvest.

Table 12: Paddy and Stover Yield of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference p | period | | | | | | | | | |
|---------------------|------------|---------------------------|-------------|-----------------------------|--------------|------------------------|------------------------------------|------------|--|--|
| | | 20 | 16 | | 2017 | | | | | |
| | Stover yie | ld (kg ha ⁻¹) | Paddy yield | <u>(kg ha⁻¹)</u> | Stover yield | (kg ha ⁻¹) | Paddy yield (kg ha ⁻¹) | | | |
| | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | <u>BUK</u> | <u>DBT</u> | | |
| Weed free period (| WF) | | | | | | | | | |
| 14 DAE | 761abc | 464.4 | 1695d | 1290d | 681de | 589c | 1543fe | 1520de | | |
| 28 DAE | 917ab | 580.8 | 1698d | 1409d | 888a-d | 821ab | 1858de | 1616d | | |
| 42 DAE | 779abc | 544.2 | 1873cd | 1453cd | 821a-d | 559c | 2086cd | 1845c | | |
| 56 DAE | 661bc | 629.7 | 2348b | 1687b | 993ab | 841a | 2528ab | 2062b | | |
| Until harvest | 1120a | 696.4 | 2840a | 1978a | 1053a | 919a | 2818a | 2454a | | |
| Weed infested peri | od (WIF) | | | | | | | | | |
| 14 DAE | 839abc | 433.6 | 2590ab | 1836bc | 1022ab | 927a | 2567ab | 2228b | | |
| 28 DAE | 835abc | 595.8 | 2202bc | 1438cd | 976abc | 522c | 2281bc | 1566d | | |
| 42 DAE | 828abc | 456.4 | 1808cd | 1378d | 786bcd | 626c | 1917cde | 1457de | | |
| 56 DAE | 906ab | 574.2 | 1772d | 1268d | 737cde | 669bc | 1620e | 1326ef | | |
| Until harvest | 431c | 312.2 | 1136e | 1038e | 544.e | 567c | 1177f | 1146f | | |
| SE ± | 272 | 285 | 265 | 142 | 150 | 111 | 263 | 150 | | |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

Table 13: Harvest Index of Upland Rice as Affected by Period of Weed Interference at BUK and DBT in 2016 and 2017 Raining Seasons

| |] | Harvest index | x (%) | |
|----------------------------|------|---------------|-------|---------|
| | 2016 | <u></u> | 2017 | |
| Weed interference period | BUK | DBT | BUK I | OBT |
| Weed free period (WF) | | | | |
| 14 DAE | 70.3 | 74.0 | 69.7 | 72.0abc |
| 28 DAE | 67.1 | 71.3 | 68.1 | 68.1bc |
| 42 DAE | 67.7 | 71.3 | 71.0 | 71.4abc |
| 56 DAE | 76.9 | 71.9 | 71.8 | 71.1abc |
| Until harvest | 70.9 | 71.1 | 71.9 | 72.7a |
| Weed infested period (WIF) | | | | |
| 14 DAE | 75.0 | 80.1 | 71.7 | 70.0abc |
| 28 DAE | 70.9 | 70.7 | 71.3 | 74.4a |
| 42 DAE | 70.0 | 76.2 | 69.1 | 69.9abc |
| 56 DAE | 69.3 | 70.4 | 69.2 | 66.4c |
| Until harvest | 75.6 | 79.1 | 68.5 | 68.1bc |
| SE± | 8.30 | 10.01 | 3.32 | 3.51 |

Means with the same letter in the same column are not significantly different ($P \le 0.05$) using SNK, DAE – Days after emergence

Determination of CPWC, CTWR and CWFP

The effect of period of weed interference on the yield of upland rice at BUK in 2016 is presented in Figure 1. The results revealed that the critical time of weed removal (CTWR), 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 (Figure 3). The Maximum rice yield loss due to weed competition was 60.0% (Table 14).

Data on the effect of weed interference on the yield of upland rice at DBT in 2016 is presented in Figure 2. The result 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 (Figure 2). The Maximum rice yield loss due to weed competition was 47.5% (Table 14).

Table 14: Effect of Weed Interference on Paddy Yield and Relative Percentage to Weed Free of Upland Rice at BUK and DBT in 2016 and 2017 Raining Seasons

| Weed interference period | | 20 | 16 | | | 20 | 17 | |
|----------------------------|--------------------------------------|-------------|---------------------------------------|-------------|--------------------------------------|-------------|---------------------------------------|-------------|
| | BU | K | | DBT | BUI | < | DBT | |
| | Paddy yield (Kgha ⁻¹) | % weed free | Paddy yield (kgha ⁻¹) | % weed free | Paddy yield (Kgha ⁻¹) | % weed free | Paddy yield (kgha ⁻¹) | % weed free |
| Weed free period (WF) | | | | | | | | |
| 14 DAE | 1694d | 59.7 | 1290d | 65.2 | 1543fe | 54.8 | 1520de | 61.9 |
| 28 DAE | 1689d | 59.5 | 1409d | 71.3 | 1858de | 65.9 | 1616d | 65.8 |
| 42 DAE | 1873cd | 66.0 | 1454cd | 73.5 | 2086cd | 74.0 | 1845c | 75.2 |
| 56 DAE | 2348b | 82.7 | 1687b | 85.3 | 2528ab | 89.7 | 2062b | 84.0 |
| At harvest | 2840a | 100 | 1978a | 100 | 2818a | 100 | 2454a | 100 |
| Weed infested period (WIF) | | | | | | | | |
| 14 DAE | 2590ab | 91.2 | 1835bc | 93.3 | 2567ab | 91.1 | 2228b | 90.8 |
| 28 DAE | 2202bc | 77.5 | 1438cd | 72.7 | 2281bc | 81.0 | 1566d | 63.8 |
| 42 DAE | 1807cd | 67.4 | 1378d | 69.7 | 1917cde | 68.0 | 1457de | 59.4 |
| 56 DAE | 1772d | 62.4 | 1267d | 64.1 | 1620e | 57.5 | 1327ef | 54.0 |
| At harvest | 1136e | 40.0 | 1038e | 52.5 | 1177f | 41.8 | 1146f | 46.7 |
| SE± | 265 | - | 142 | - | 263 | - | 150 | - |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, DAE – Days after emergence, BUK – Bayero University Kano, DBT – Thomas dam Dambatta

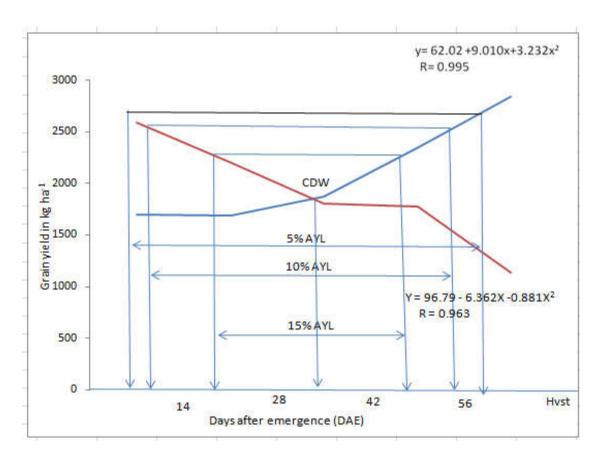


Figure 1: Effect of critical period of weed interference on upland rice yield at BUK in 2016 raining season

AYL – allowable yield loss, hvst – harvest, CDW - critical date for weeding

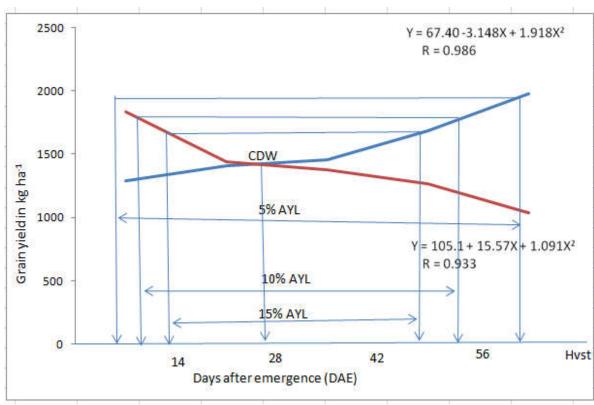


Figure 2: Effect of critical period of weed interference on upland rice yield at DBT in 2016 raining season

AYL – allowable yield loss, hvst – harvest, CDW - critical date for weeding

Table 15: Critical Time for Weed Removal (CTWR), Critical Weed Free Period (CWFP) and Critical Period of Weed Control (CPWC) in Upland Rice Base on Three levels of Allowable

yield loss (AYL) at BUK and DBT during 2016 and 2017 Raining Seasons

| j i dia i d | 00 (111 | \mathbf{c}_{j} at \mathbf{c}_{j} | orr and | DD1 G | <u> </u> | 10 ana | <u> </u> | ming se | 450115 | | | | |
|-------------|-----------|--------------------------------------|-----------|------------|-----------|------------|-----------|-------------|-------------------------|-------------|------|------------|--|
| AYL | | <u>CTWR</u> | (DAE) | | | <u>CTW</u> | R (DAE) | | Duration of CPWC | | | | |
| (%) | | | | | | | | | | <u>(Da</u> | ays) | | |
| | <u>20</u> | <u> 16</u> | <u>20</u> | <u> 17</u> | <u>20</u> | <u> 16</u> | <u>20</u> | <u>2017</u> | | <u>2016</u> | | <u> 17</u> | |
| | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT | |
| | | | | | | | | | | | | | |
| 5 | 10 | 10 | 15 | 8 | 66 | 64 | 64 | 68 | 56 | 54 | 49 | 60 | |
| | | | | | | | | | | | | | |
| 10 | 16 | 16 | 21 | 12 | 62 | 61 | 58 | 63 | 46 | 45 | 37 | 51 | |
| | | | | | | | | | | | | | |
| 15 | 23 | 21 | 26 | 17 | 59 | 54 | 53 | 56 | 36 | 33 | 27 | 39 | |
| | | | | | | | | | | | | | |

DAE – days after emergence

The effect of weed interference on the yield of upland rice at BUK in 2017 is presented in Figure 3. The result revealed that the critical time of weed removal, based on 5% yield loss level ended at 15 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 21 DAE and the critical weed free period occurred at 58 DAE, based on 15% AYL, the critical time of weed removal ended 26 DAE and the critical time of weed free period occurred at 53 DAE. The duration of critical period for weed control is 49, 37 and 27 days for 5, 10 and 15% AYL respectively. The critical date for weeding is 38 DAE (Figure 3). The Maximum rice yield loss due to weed competition was 58.2% (Table 14).

The effect of weed interference on the yield of upland rice at DBT in 2017 is presented in Figure 4. The result revealed that the critical time of weed removal, based on 5% yield loss level ended at 8 DAE and the critical weed free period occurred at 68 DAE. At 10% AYL on the other hand, the critical time of weed removal ended at 12 DAE and the critical weed free period occurred at 63 DAE, based on a 15% AYL, the critical time of weed removal ended at 17 DAE and the critical time of weed free period occurred at 56 DAE. The duration of critical period for weed control is 60, 51 and 39 days for 5, 10 and 15% AYL, respectively. The critical date for weeding is 30 DAE (Figure 4). The Maximum rice yield loss due to weed competition was 53.3% (Table 14).

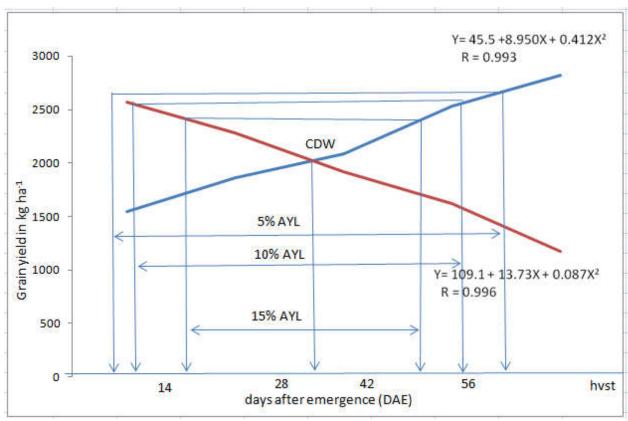


Figure 3: Effect of critical period of weed interference on upland rice yield at BUK in 2017 raining season

AYL – allowable yield loss, hvst – harvest, CDW - critical date for weeding

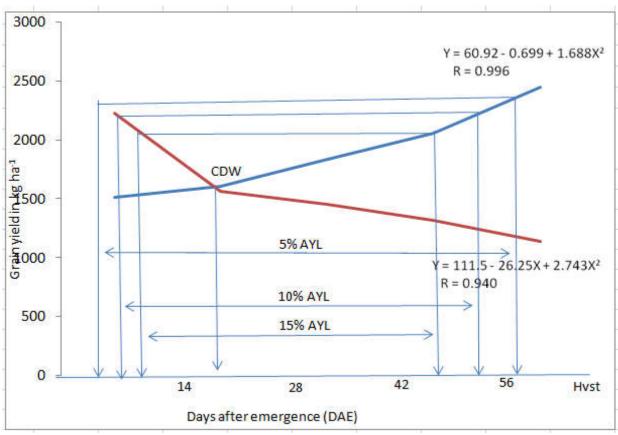


Figure 4: Effect of critical period of weed interference on upland rice yield at DBT in 2017 raining season

AYL – allowable yield loss, hvst – harvest, CDW - critical date for weeding

Cost-benefit analysis of weed interference periods

Analysis of cost-benefit ratio as affected by different periods of weed interference on growing upland rice for BUK and DBT in 2016 raining seasons is presented in Figure 5. It could be observed that at BUK in 2016 weed free until harvest produced the highest cost-benefit (C:B) ratio of 1.52 Naira for every Naira invested and this was closely followed by weed infested at 14 DAE that gave 1.47 Naira cost-benefit ratio for every one Naira invested and also closely followed by free at 56 DAE with 1.33 while the least and loss figure was recorded by the weed infested until harvest with C:B ratio of 0.86. At DBT in 2016 weed free until harvest recorded the highest cost-benefit ratio of 1.10 Naira for every Naira invested and this was closely followed by weed infested at 14 DAE that gave 1.04 Naira cost-benefit ratio for every one Naira invested while all other treatments recorded lost figure.

In 2017 raining season at BUK (Figure 6), similarly, weed free at harvest recorded the highest cost-benefit ratio of 1.51 Naira for every Naira invested and this was closely followed by weed infested at 14 DAE that gave 1.45 Naira cost-benefit ratio and also closely followed by free at 56 DAE with 1.43, while the least and loss figure was recorded by weed infested until harvest with C:B ratio of 0.90. It was also documented that at DBT in 2017 weed free until harvest had the highest cost-benefit ratio of 1.31 Naira for every Naira invested and this was closely followed by weed infested at 14 DAE that gave 1.27 Naira cost-benefit ratio, while the least and lost figure was recorded by the weed infested until harvest with C:B ratio of 0.93.

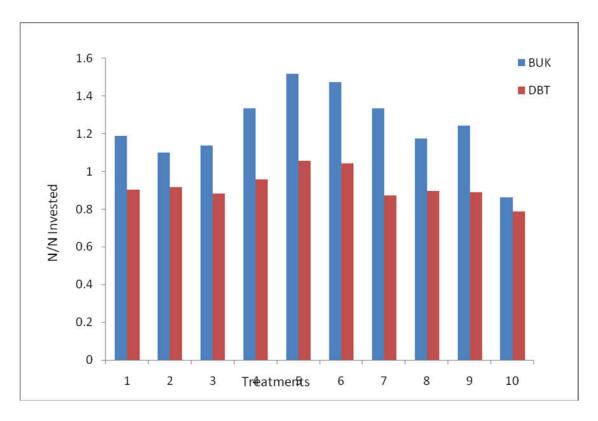


Figure 5: Cost – benefit ratio as affected by weed interference periods for BUK and DBT in 2016 raining season

Key to figures 7 and 8:

1 = Weed free at 14 DAE
2 = Weed free at 28 DAE
3 = Weed free at 42 DAE
4 = Weed free at 56 DAE
5 = Weed free at harvest
6 = Weed infested at 14 DAE
7 = Weed infested at 28 DAE
8 = Weed infested at 42 DAE
9 = Weed infested at 56 DAE

N/N invested = Naira per naira invested

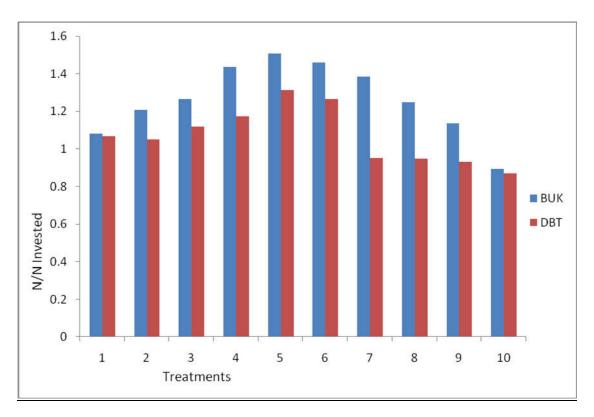


Figure 6: Cost – benefit ratio as affected by weed interference periods for BUK and DBT in 2017 raining season

Key to figures 7 and 8:

1 = Weed free at 14 DAE
2 = Weed free at 28 DAE
3 = Weed free at 42 DAE
4 = Weed free at 56 DAE
5 = Weed free at harvest
6 = Weed infested at 14 DAE
7 = Weed infested at 28 DAE
8 = Weed infested at 42 DAE
9 = Weed infested at 56 DAE

N/N invested = Naira per naira invested

4.1.4 Weed Control Methods

Weed species and phytosociological characteristics

The weed species composition and their Phytosociological Characteristics at BUK and DBT during 2016 raining seasons is presented in Table 16. There were a total of 13 weed species identified at BUK, with grass family being six, and broad leaved being five, while sedges are two. Similarly at DBT also a total of 13 weed species were identified, five were grasses, four were broad leaved and sedges each. At BUK site *Rottboellia cochinchinensis* had the highest number of frequency and relative frequency, density and relative density and importance value index (IVI). However, *Fimbryistylis furreginea* had the highest abundance and relative abundance while *Commelina benghalensis* had the lowest abundance and relative abundance but the lowest density and relative density and importance value index was recorded from *Cyperus esculantus*. DBT weed species composition revealed *Digitaria horizontalis* to have the highest frequency and relative frequency, density and relative density and importance value index while *Cynodon dactylon* had the highest abundance and relative abundance. *Rottboellia cochinchinensis* here occupied the laest density, frequency and importance value index position.

Table 16: Weed Species and their Phytosociological Characteristics at BUK and DBT during 2016 Raining Season

| Weed Species | | | | BUK | | | | | | | | DBT | | |
|------------------------------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|
| | ABD | RA % | DST | RD % | FRQ | RF % | IVI | ABD | RA % | DST | RD % | FRQ | RF % | IVI |
| Grasses | | | | | | | | | | | | | | |
| R. cochinchinensis (Lour.) | | | | | | | 102.4 | | | | | | | 4.5 |
| Clayton | 4.31 | 8.4 | 3.29 | 51.7 | 76.3 | 42.3 | | 2.00 | 3.8 | 0.03 | 0.2 | 1.3 | 0.5 | |
| I. cylindrica (L.) Raeuschel | - | - | - | - | - | - | - | 3.29 | 6.3 | 0.29 | 2.5 | 8.8 | 3.5 | 12.3 |
| P. maximum Jacq | 5.50 | 10.7 | 0.14 | 2.2 | 2.5 | 1.4 | 14.3 | - | - | - | - | - | - | - |
| D. horizontalis Willd | 4.50 | 8.8 | 0.11 | 1.7 | 2.5 | 1.4 | 11.9 | 4.81 | 9.2 | 4.03 | 34.4 | 83.8 | 33.2 | 76.8 |
| C. dactylon (L) Pers. | 2.56 | 5.0 | 0.29 | 4.6 | 11.3 | 6.3 | 15.9 | 7.41 | 14.1 | 3.61 | 30.9 | 48.8 | 19.3 | 64.3 |
| E. indica (Gaertn.) | 3.50 | 6.8 | 0.09 | 1.4 | 2.5 | 1.4 | 9.6 | 1.83 | 3.5 | 0.14 | 1.2 | 7.5 | 3.0 | 7.7 |
| Broad leaved | | | | | | | | | | | | | | |
| I. asarifolia (Desr.) Roem. | 2.33 | 4.5 | 0.79 | 12.4 | 2.5 | 1.4 | 11.9 | 2.67 | 5.1 | 0.20 | 1.7 | 7.5 | 3.0 | 9.8 |
| S. occidentalis (L.) Link | 4.50 | 8.8 | 0.11 | 1.7 | 5.0 | 2.8 | 17.1 | - | - | - | - | - | - | - |
| A. spinosus (L). | 5.25 | 10.2 | 0.26 | 4.1 | 33.8 | 18.6 | 35.5 | 2.33 | 4.4 | 0.09 | 0.8 | 3.8 | 1.5 | 6.7 |
| A. hispidum (DC) | - | - | - | - | - | - | - | 3.33 | 6.3 | 0.25 | 2.1 | 7.5 | 3.0 | 11.4 |
| T. procumbens (L.) | 2.53 | 4.9 | 0.54 | 8.5 | 21.3 | 11.8 | 25.2 | 2.56 | 4.9 | 0.51 | 4.4 | 20.0 | 7.9 | 17.2 |
| P. amarus (Schum.&Thon). | 3.17 | 6.7 | 0.24 | 3.8 | 7.5 | 4.2 | 12.9 | - | - | - | - | - | - | - |
| C. retusa (L.) | 1.63 | 3.2 | 0.16 | 2.5 | 10.0 | 5.6 | 11.3 | - | - | - | - | - | - | - |
| C. benghalensis (L.) | 1.63 | 3.2 | 0.16 | 2.5 | 10.0 | 5.6 | 11.3 | - | - | - | - | - | - | - |
| Sedges | | | | | | | | | | | | | | |
| L. hexandra (Sw.) | - | - | - | - | | | | 3.18 | 6.1 | 0.44 | 3.7 | 13.8 | 5.5 | 15.3 |
| C. esculentus (L) | 4.00 | 7.8 | 0.05 | 0.8 | 1.3 | 0.7 | 9.3 | 4.83 | 9.2 | 0.36 | 3.1 | 7.5 | 3.0 | 15.3 |
| K. squamulata (Thonn.) | - | - | - | - | - | - | - | 4.00 | 7.6 | 1.35 | 11.6 | 33.8 | 13.4 | 32.6 |
| F. ferruginea (L.) Vahl | 7.67 | 14.9 | 0.29 | 4.6 | 3.8 | 2.1 | 21.6 | 6.50 | 12.4 | 0.16 | 1.4 | 2.5 | 1.0 | 14.8 |

ABD – abundance, RA – relative abundance, DST – density, RD – relative density, FRQ – frequency, RF – relative frequency, IVI – importance value index

The weed Phytosociological Characteristics of BUK and DBT in 2017 wet season is presented in Table 17. There were a total of 16 weed species identified at BUK, weeds from grass family are seven, broad leaved weeds were five while sedges are four. Similarly at DBT also a total of 14 weed species were identified, four were grasses, seven and three were broad leaved and sedges respectively. At BUK Rottboellia cochinchinensis had the highest number of abundance (37.3) and relative abundance (35.5%), frequency (21.9) and relative frequency (21.2%), as well as importance value index (65.3). Eleucine indica had the highest density (7) and relative density (11.4%), and Imperata cylindrica resulted in the lowest abundance and relative abundance and density and relative density while panicum maximum, eleucine indica and leersia hexandra had the lowest frequency and relative frequency. At DBT, however, Digitaria horizontalis had the highest abundance (43.3) and relative abundance (21.1%), density (67.5) and relative density (23.3%) and importance value index (52.1) but Cyperus esculentus had the highest frequency of 6.5 and relative frequency of 10% and the lowest density, frequency and importance value index in this location goes to Rottboellia cochinchinensis.

Table 17: Weed Species and Phytosociological Characteristics of BUK and DBT during 2017 Raining Season

| Weed Species | | | | BUK | | | | | | | | DBT | | |
|------------------------------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|
| | ABD | RA % | DST | RD % | FRQ | RF % | IVI | ABD | RA % | DST | RD % | FRQ | RF % | IVI |
| Grasses | | | | | | | | | | | | | | |
| R. cochinchinensis (Lour.) | | | | | 24.00 | | c= 0 | | | | | | | |
| Clayton | 37.3 | 35.5 | 5.33 | 8.6 | 21.88 | 21.2 | 65.3 | - | - | - | - | - | - | - |
| I. cylindrica (L.) Raeuschel | 1.3 | 1.2 | 1.33 | 2.2 | 3.13 | 3.0 | 6.4 | - | - | - | - | - | - | - |
| P. maximum Jacq | 3.3 | 3.1 | 5.00 | 8.1 | 2.08 | 2.0 | 13.2 | 3 | 1.5 | 7.5 | 2.6 | 4.81 | 7.4 | 11.5 |
| D. horizontalis Willd | 6.0 | 5.7 | 6.00 | 9.7 | 3.13 | 3.0 | 18.4 | 43.3 | 21.1 | 67.5 | 23.3 | 5.04 | 7.7 | 52.1 |
| C. dactylon (L) Pers. | 8.0 | 7.6 | 3.00 | 4.9 | 8.33 | 8.1 | 20.6 | 43.7 | 21.2 | 65 | 22.3 | 5.25 | 8.1 | 61.6 |
| E. indica (Gaertn.) | 4.7 | 4.5 | 7.00 | 11.4 | 2.08 | 2.0 | 17.9 | 28 | 13.6 | 40 | 13.8 | 4.17 | 6.4 | 33.8 |
| Broad leaved | | | | | | | | | | | | | | |
| I. asarifolia (Desr.) Roem. | 21.0 | 19.9 | 4.85 | 7.9 | 13.54 | 13.1 | 40.9 | 8.3 | 4.0 | 15 | 5.2 | 4.67 | 7.2 | 16.4 |
| S. occidentalis (L.) Link | 4.0 | 3.8 | 2.40 | 3.9 | 5.21 | 5.0 | 12.7 | 4.7 | 2.3 | 7.5 | 2.6 | 5.4 | 8.3 | 13.2 |
| A. spinosus (L). | 4.7 | 4.5 | 3.50 | 5.7 | 4.17 | 4.0 | 14.2 | 9 | 4.4 | 12.5 | 4.3 | 3.6 | 5.5 | 14.2 |
| A. hispidum (DC) | - | - | - | | - | - | | 7 | 3.4 | 10 | 3.4 | 5.43 | 8.3 | 15.1 |
| T. procumbens (L.) | 21.3 | 20.2 | 4.57 | 7.4 | 14.58 | 14.1 | 41.7 | 12.7 | 6.2 | 17.5 | 6.0 | 4.5 | 6.9 | 19.1 |
| P. amarus (Schum.&Thon). | 8.0 | 7.6 | 2.67 | 4.3 | 9.38 | 9.1 | 21.0 | 6 | 2.9 | 10 | 3.4 | 4.4 | 6.8 | 13.1 |
| C. retusa (L.) | - | - | - | - | - | - | - | 6 | 2.9 | 12.5 | 4.3 | 5.25 | 8.1 | 15.3 |
| C. benghalensis (L.) | 4.0 | 3.8 | 6.00 | 9.7 | 2.08 | 2.0 | 15.5 | - | - | - | - | - | - | - |
| Sedges | | | | | | | | | | | | | | |
| L. hexandra (Sw.) | 2.0 | 1.9 | 3.00 | 4.9 | 2.08 | 2.0 | 8.8 | - | - | - | - | - | - | - |
| C. esculentus (L) | 3.7 | 3.5 | 3.67 | 6.0 | 7.5 | 7.3 | 16.8 | 4.3 | 2.1 | 5 | 1.7 | 6.5 | 10.0 | 13.8 |
| K. squamulata (Thonn.) | 4.3 | 4.1 | 6.50 | 10.5 | 3.13 | 3.0 | 17.6 | 18.7 | 9.7 | 30 | 10.3 | 4.7 | 7.2 | 27.2 |
| F. ferruginea (L.) Vahl | 2.8 | 2.7 | 2.83 | 4.6 | 3.13 | 3.0 | 10.3 | 3.7 | 1.8 | 5 | 1.7 | 5.5 | 8.5 | 12.0 |
| | | | | | | | | | | | | | | |

ABD – abundance, RA – relative abundance, DST – density, RD – relative density, FRQ – frequency, RF – relative frequency, IVI – importance value index

Weed dry weight (g)

Effect of weed control strategies on weed dry weight at BUK and DBT in 2016 and 2017 raining seasons is presented in Table 18. The result on weed dry weight (WDW) was significantly different ($P \le 0.05$) at all the locations and growing seasons. The lowest WDW at BUK in 2016 was recorded by the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8WAS but was at par with Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha-1, Butachlor at 1.5 kg a.i.ha-1 fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹. The weedy check produced the significantly heaviest WDW. Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS at DBT in 2016 raining season recorded the lightest WDW though, they were at par with Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, HWC at 2, 4, 6 & 8WAS, Butachlor at 1.5 kg a.i.ha-1 fb SHW at 4 and Butachlor at 1.5 kg a.i.ha-1 fb SHW at 8 WAS. Similarly, the weedy check produced the significantly heaviest WDW.

In 2017 wet season at BUK, the lightest WDW was produced by HWC at 2, 4, 6 and 8 WAS but was at par with application of Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹. The weedy check produced the significantly heaviest WDW. At DBT in 2017 raining season on the other

hand, The lightest WDW was produced by Butachlor at 1.5 kg a.i.ha-¹ fb Orizo plus at 4.5 kg a.i.ha-¹ but was at par with Butachlor at 1.5 kg a.i.ha-¹ fb Rbow at 0.025 kg a.i.ha-¹, Butachlor at 1.0 kg a.i.ha-¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6 and 8 WAS, while the heaviest WDW was recorded by the weedy check.

Weed control efficiency (%)

Effect of weed control strategies on weed control efficiency (WCE) at BUK and DBT in 2016 and 2017 raining seasons is presented in Table 18. Weed control efficiency was significantly affected by the methods of weed control at all the locations and growing seasons. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS produced the highest control efficiency but was at par with application of Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS, at 4 & 8 WAS, HWC at 2,4,6 & 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ at BUK in 2016 raining season. At DBT in the same period, however, HWC at 2,4,6 & 8 WAS recorded the highest WCE but was at par with Butachlor at 1 kg a.i.ha⁻¹ fb SHW at 4 and at 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4, and at 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4, and at 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS.

In 2017 raining season at BUK the highest WCE was produced by HWC at 2, 4, 6 & 8 WAS but at par with considerable number of treatments, while at DBT it was obtained by Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, despite the greater variations it was at par with Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, HWC at 2, 4, 6 & 8 WAS and some other few treatments (Table 18).

Table 18: Weed Dry Weight and Weed Control Efficiency of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | 2016 | | | | 2017 | | | |
|-------------------------|------------------------|----------------|----------|----------------|---------|----------------|----------|---------|---------|
| | a.i.ha ⁻¹) | | | | | | | | |
| | | <u>WDW (g)</u> | | <u>WCE (%)</u> | | <u>WDW (g)</u> | | WCE (%) | |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 168.0c-g | 113.0b | 44.2efg | 29.5d | 133.0c-f | 90c-f | 42.6c-f | 55.4b-e |
| Buta fb Orizo | 1.0 fb 4.5 | 138.3c-i | 104.0bc | 50.0b-g | 35.8cd | 151.8def | 86.0c-f | 37.7def | 60.3b-e |
| Buta fb Orizo | 1.5 fb 2.8 | 109d-i | 123.3b | 66.2a-e | 23.3d | 92.5efg | 97.0cde | 64.1abc | 70.7ab |
| Buta fb Orizo | 1.5 fb 4.5 | 93.5e-i | 92.0bcd | 69.2a-e | 43.4bcd | 72.0fg | 52.3g | 70.3ab | 75.4a |
| Buta fb Rbow | 1 fb 0.025 | 130.5d-i | 94.3bcd | 69.2a-e | 40.8bcd | 108.bcdf | 89.3c-f | 54.8-d | 57.9b-e |
| Buta fb Rbow | 1 fb 0.030 | 222b | 116.5b | 29.5g | 28.6d | 186.5cd | 103.5cd | 23.8efg | 51.9def |
| Buta fb Rbow | 1.5 fb 0.025 | 191c-f | 97.8bcd | 34.3fg | 39.4bcd | 86.4def | 76.4c-g | 66.0abc | 64.0a-d |
| Buta fb Rbow | 1.5 fb 0.030 | 210.8cde | 96.0bcd | 46.8c-g | 40.4bcd | 119.3def | 97.5cde | 51.1a-d | 54.5cde |
| Buta fb Solito | 1 fb 0.32 | 154.3b-g | 97.5bcd | 46.8c-g | 39.6bcd | 188.0f | 117.bcf | 23.3efg | 44.5ef |
| Buta fb Solito | 1 fb 0.48 | 161.9b-h | 94.3bcd | 44.9d-g | 41.4bcd | 196.0d | 136.5b | 18.8fg | 36.9f |
| Buta fb Solito | 1.5 fb 0.32 | 218.5cd | 100.8bcd | 26.3g | 37.3bcd | 107.8efg | 98.8cde | 53.9a-d | 54.2cde |
| Buta fb Solito | 1.5 fb 0.48 | 125.3d-i | 98.8bcd | 56.6a-f | 39.8bcd | 136.0c-f | 102.0cd | 44.1cde | 51.5def |
| Buta fb SHW @ 4 WAS | 1.0 | 75.3hi | 72.3cde | 73.7abc | 54.4abc | 89.3bcd | 107.3bcd | 62.4a-d | 49.7def |
| Buta fb SHW @ 8 WAS | 1.0 | 61.3i | 95.6cde | 79.5a | 53.0abc | 139.0c-f | 98.3cde | 40.5c-f | 53.7de |
| Buta fb SHW @ 4 WAS | 1.5 | 80.3ghi | 70.5de | 71.8a-g | 56.3abc | 97.5bcd | 89.8c-f | 61.3a-d | 54.6b-e |
| Buta fb SHW @ 8 WAS | 1.5 | 61.5i | 68.0de | 79.6a | 57.4ab | 117.8bcd | 112.5bc | 51.9a-d | 56.6ef |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 79.0ghi | 55.5e | 74.1ab | 65.8a | 121.3b-e | 97.0efg | 45.6b-e | 55.8b-e |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 66.5i | 51.3e | 77.5ab | 62.2a | 134.3c-f | 90.5c-f | 45.3b-e | 57.6b-e |
| HWC @ 2, 4, 6 & 8 WAS | _ | 92.3hi | 52.3e | 69.7a-e | 67.1a | 59.8g | 65.3efg | 74.1a | 69.7abc |
| Weedy check | _ | 305a | 161.0a | _ | _ | 262.3a | 215.3a | _ | _ |
| SE ± | | 50.91 | 20.32 | 16.30 | 12.61 | 40.12 | 20.41 | 15.42 | 9.41 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, WDW – weed dry weight, WCE – weed control efficiency, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta – Butachlor, Rbow = Rainbow (Penoxsulam oil) ,Solito = Pretilachlor + Pyribenzoxim

Weed cover score

Effect of weed control strategies on weed cover score at BUK and DBT in 2016 and 2017 raining seasons is presented in Table 19. Data recorded on weed cover score (WCS) produced significant differences ($P \le 0.05$) at all the locations, years and sampling periods. The weedy check recorded the highest WCS at both locations and growing seasons except at BUK in 2017 during 4 WAS sampling period. At BUK in 2016 the weedy check was at par with all the treatments except Butachlor at 1.5 kg a.i. Butachlor at ha⁻¹ fb Orizo plus at 4.5 kg a.i. ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and the HWC. At DBT the weedy check was at par only with Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 4.5 k g a.i. ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rbow at 0.030 kg a.i.ha⁻¹ and Butachlor at 1.5 kg a.i.ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹.

In 2017 raining saeson at BUK the lowest weed cover score was recorded by Butachlor application at 1 kg a.i.ha⁻¹ fb SHW 4 WAS and fb SHW at 8 WAS during 4 WAS, though it is at par with Butachlor 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6 & 8 WAS. Similarly in the same year during 4 WAS at DBT, weedy check had the the highest WCS but was at par with Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ and Butachlor at 1 kg a.i.ha⁻¹ fb Solito at 0.32 k g a.i. ha-1. During 8 WAS sampling in 2017 the least WCS was produced by Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ though was at par with all of the treatments except Butachlor 1.0 kg a.i.ha⁻¹ fb 1.5 kg a.i.ha⁻¹, Butachlor at 1 kg a.i.ha⁻¹ fb Solito at 0.32 k g a.i. ha-1, Butachlor at 1 kg a.i.ha⁻¹ fb SHW at 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS at BUK. However, at DBT in the

corresponding period Butachlor applied at 1 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS had the least WCS though statistically similar with majority of the treatments. The weedy check recorded the highest WCS throughout the experiment by statistical ranking.

Table 19: Weed Cover Score of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | 2016 | | | | 2017 | | | |
|-------------------------|------------------------|-------------|--------|-------------|--------|-------------|--------|-------------|--------|
| | a.i.ha ⁻¹) | | | | | | | | |
| | | WCS @ 4 WAS | | WCS @ 8 WAS | | WCS @ 4 WAS | | WCS @ 8 WAS | |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 5.8e | 3.3a-d | 5.3-cde | 3.0ab | 3.8abc | 3.3a-d | 4.5abc | 3.0ab |
| Buta fb Orizo | 1.0 fb 4.5 | 5.3e | 5.8ef | 5.0b-e | 5.8cd | 4.2a-e | 5.8ef | 6.3b-e | 5.8cd |
| Buta fb Orizo | 1.5 fb 2.8 | 4.5b-e | 7.5f | 5.5de | 7.5de | 4.8a-e | 7.5f | 4.3a | 7.5de |
| Buta fb Orizo | 1.5 fb 4.5 | 3.0abc | 4.3b-e | 4.8a-e | 2.5ab | 3.8abc | 4.0a-d | 3.3a | 2.8ab |
| Buta fb Rbow | 1.0 fb 0.025 | 5.5ce | 4.3b-e | 4.8a-e | 3.5abc | 5.0cde | 4.3a-d | 4.8abc | 3.5abc |
| Buta fb Rbow | 1.0 fb 0.030 | 5.3cde | 4.0b-e | 5.8de | 4.5bc | 4.8b-e | 4.0a-d | 4,3bcd | 4.5bc |
| Buta fb Rbow | 1.5 fb 0.025 | 5.5de | 4.0b-e | 5.5de | 3.5abc | 5.0cde | 4.0a-d | 5.6a-d | 3.5abc |
| Buta fb Rbow | 1.5 fb 0.030 | 6.8e | 6.3fe | 6.0e | 3.8abc | 5.0cde | 4.0a-d | 4.3abc | 3.8abc |
| Buta fb Solito | 1.0 fb 0.32 | 5.8e | 6.3ef | 5.3cde | 5.8cd | 6.5de | 5.3de | 7.5de | 5.8cd |
| Buta fb Solito | 1.0 fb 0.48 | 5.9e | 4.5def | 5.5ed | 4.3bc | 6.8e | 4.5bcd | 5.8a-d | 4.3bc |
| Buta fb Solito | 1.5 fb 0.32 | 6.5e | 4.5def | 6.0e | 4.5bc | 5.8cde | 4.8bcd | 6.5b-e | 4.5bc |
| Buta fb Solito | 1.5 fb 0.48 | 6.0e | 5.0def | 6.0e | 4.5bc | 6.0cde | 5.0bcd | 5.5a-d | 4.5bc |
| Buta fb SHW @ 4 WAS | 1.0 | 4.5b-e | 3.3a-d | 3.3a-e | 3.0ab | 1.8a | 3.3a-d | 4.8abc | 3.0ab |
| Buta fb SHW @ 8 WAS | 1.0 | 2.5ab | 4.8def | 3.0a-f | 3.3ab | 1.8a | 4.4bcd | 6.8cde | 3.3ab |
| Buta fb SHW @ 4 WAS | 1.5 | 2.8ab | 5.3ef | 2.5abc | 4.4bc | 2.0a | 5.3ef | 3.8ab | 4.3bc |
| Buta fb SHW @ 8 WAS | 1.5 | 2.0a | 2.8abc | 2.0a | 2.3ab | 6.0def | 2.8abc | 7.8de | 2.3ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 2.8ab | 1.5a | 2.5abc | 1.8a | 2.3ab | 1.5a | 3.3a | 1.2a |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 2.3ab | 3.0a-d | 2.3ab | 2.8ab | 3.8abc | 3.0a-d | 4.8abc | 2.8ab |
| HWC @ 2, 4, 6 & 8 WAS | _ | 3.3ab | 2.0ab | 2.5abc | 2.8ab | 3.8abc | 2.0ab | 3.8ab | 2.8ab |
| Weedy check | _ | 6.0e | 7.8f | 9.0f | 8.0e | 6.5ef | 7.8f | 8.8e | 8.0e |
| SE ± | | 1.41 | 1.42 | 1.71 | 1.44 | 1.54 | 1.89 | 1.62 | 0.95 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, WCS – weed cover score, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta – Butachlor,

^{*}WCS = Using a scale of 1 - 9 where 1 represent no weed cover and 9 completely weedy plot

4.1.2 Crop Growth Parameters

Establishment count (%)

Performance of weed control methods on establishment count for BUK and DBT in 2016 and 2017 raining seasons is presented in Table 20. Significant difference was recorded only at DBT in both seasons. HWC at 2, 4, 6 & 8 WAS recorded the significantly highest establishment count in both seasons, however, it was statistically similar with all the treatments except the weedy check that recorded the lowest result in 2016 at DBT. In 2017 raining season this same best treatment was at par only with Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow 0.030 kg a.i ha⁻¹ at the same location.

Table 20: Establishment Count of Upland Rice as Affected by Weed Control Strategies at

BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | Establishme | nt count (| <u>%)</u> |
|-------------------------|---------------------------------|------|-------------|------------|--------------|
| | | | 2016 | | <u> 2017</u> |
| | | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 51.3 | 53.8ab | 53.3 | 52.3bc |
| Buta fb Orizo | 1.0 fb 4.5 | 50.3 | 58.6ab | 60.0 | 50.2bc |
| Buta fb Orizo | 1.5 fb 2.8 | 45.9 | 59.4ab | 55.9 | 50.6bc |
| Buta fb Orizo | 1.5 fb 4.5 | 66.8 | 51.3ab | 62.9 | 50.2bc |
| Buta fb Rbow | 1 fb 0.025 | 47.1 | 49.0ab | 56.3 | 61.0bc |
| Buta fb Rbow | 1 fb 0.030 | 69.8 | 40.1ab | 46.8 | 49.5bc |
| Buta fb Rbow | 1.5 fb 0.025 | 73.0 | 67.9ab | 56.1 | 46.1bc |
| Buta fb Rbow | 1.5 fb 0.030 | 60.9 | 47.8ab | 56.5 | 67.5ab |
| Buta fb Solito | 1.0 fb 0.32 | 45.1 | 59.8ab | 72.3 | 50.8bc |
| Buta fb Solito | 1.0 fb 0.48 | 49.5 | 58.8ab | 61.1 | 47.2bc |
| Buta fb Solito | 1.5 fb 0.32 | 54.5 | 45.7ab | 57.1 | 49.4bc |
| Buta fb Solito | 1.5 fb 0.48 | 54.1 | 65.6ab | 66.9 | 53.5b |
| Buta fb SHW @ 4 WAS | 1.0 | 62.3 | 60.3ab | 63.6 | 48.5bc |
| Buta fb SHW @ 8 WAS | 1.0 | 57.0 | 49.8ab | 58.5 | 40.5c |
| Buta fb SHW @ 4 WAS | 1.5 | 53.1 | 44.2ab | 60.0 | 56.3bc |
| Buta fb SHW @ 8 WAS | 1.5 | 74.4 | 49.1ab | 59.1 | 48.7bc |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 51.1 | 40.1ab | 54.7 | 53.3bc |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 55.0 | 51.1ab | 54.1 | 52.7bc |
| HWC @2, 4, 6 & 8 WAS | _ | 51.1 | 72.0a | 54.1 | 83.5a |
| Weedy check | _ | 43.4 | 38.5b | 51.1 | 48.3bc |
| SE ± | | 20.3 | 18.1 | 14.9 | 10.4 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Plant height (cm)

Effects of the weed control strategies on plant height at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 21. There were significant differences on the effect of weed control methods on plant height at all the locations, growing seasons and sampling periods. It could be observed that application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo Plus at 4.5 kg a.i.ha⁻¹ recorded the significantly tallest plants at both locations and growing seasons, except at DBT in 2017 during 4 and 8 WAS where HWC at 2, 4, 6 & WAS that produced the statistically tallest plant. However, Butachlor application at 1.5 kg a.i.ha⁻¹ fb Orizo Plus at 4.5 kg a.i.ha⁻¹ was statistically at par with Butachlor at 1 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 and at 8 WAS, Butachlor at 1 and at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6 & 8 WAS both locations during 4 WAS in 2016. At 8 WAS sampling at BUK in 2016 raining season indicated the best treatment to be at par with Butachlor at 1 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹ and Butachlor at 1 kg a.i.ha⁻¹ fb Rainbow at 0.025 kg a.i.ha⁻¹. Result from DBT in the same year (2016) indicated it to be only at par with Butachlor at 1 kg a.i.ha⁻¹ fb Rainbow SD at 25 g a.i.ha⁻¹.

In 2017 raining season at BUK the best treatment (Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo Plus at 4.5 kg a.i.ha⁻¹) was at par with the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1 kg a.i.ha⁻¹ fb Rainbow OD at 25 g a.i.ha⁻¹, Butachlor at 1 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6 & 8 WAS during 4 WAS. Similarly in the same year, location and treatment, was only at par with Butachlor at 1 kg a.i.ha⁻¹ fb Rainbow OD at

25 g a.i.ha⁻¹ during 8 WAS sampling. At DBT also in 2017 the weed free treatment (HWC at 2, 4, 6 & 8 WAS) had the tallest plant at both sampling, but was at par with most of the treatments except the weedy check and few others that had the significantly shortest plant

Table 21: Plant Height (cm) of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | | 2016 | | | 20 |)17 | |
|-------------------------|------------------------------------|---------|----------------------------------------------|--------|----------|---------|----------|---------|---------|
| | , | 4 WAS | <u>; </u> | 8 WA | <u>S</u> | 4 WAS | <u> </u> | 8_W | AS |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 46.3a-e | 42.4a-d | 70.5ab | 63.0bcd | 32.8de | 30.0ab | 61.5cd | 88.0abc |
| Buta fb Orizo | 1.0 fb 4.5 | 42.3de | 41.5a-e | 63.3b | 60.8bcd | 47.5abc | 34.7ab | 71.8bcd | 60.7bc |
| Buta fb Orizo | 1.5 fb 2.8 | 51.3abc | 32.3ef | 70.8ab | 56.5bcd | 46.3bc | 45.8ab | 72.3bcd | 77.3abc |
| Buta fb Orizo | 1.5 fb 4.5 | 54.0a | 49.8a | 83.5a | 80.5a | 59.0a | 47.7ab | 93.8a | 88.7abc |
| Buta fb Rbow | 1.0 fb 0.025 | 42.3de | 39.0bc | 68.8ab | 69.5ab | 56.3ab | 23.0ab | 72.8abc | 43.3c |
| Buta fb Rbow | 1.0 fb 0.030 | 43.3cde | 37.8b-e | 60.3bc | 53.3cd | 42.0cd | 30.3ab | 60.3cd | 57.0bc |
| Buta fb Rbow | 1.5 fb 0.025 | 53.8a | 39.8b-e | 66.0b | 57.8bcd | 42.4cd | 26.0b | 63.6bcd | 65.0bc |
| Buta fb Rbow | 1.5 fb 0.030 | 43.0cde | 43.8a-d | 57.0bc | 65.5bc | 44.3bcd | 31.0ab | 65.0bcd | 77.3abc |
| Buta fb Solito | 1 fb 0.32 | 52.5ab | 35.0def | 66.3b | 51.3cde | 42.3cd | 40.8ab | 67.5bcd | 71.5abc |
| Buta fb Solito | 1 fb 0.48 | 51.0a-d | 38.3b-e | 63.5b | 54.0bcd | 43.5bcd | 29.3b | 71.3bcd | 66.3bc |
| Buta fb Solito | 1.5 fb 0.32 | 43.8b-e | 40.0b-e | 56,5bc | 54.5bcd | 42.8cd | 28.5b | 62.5bcd | 52.3c |
| Buta fb Solito | 1.5 fb 0.48 | 42.0e | 36.5b-f | 57.8bc | 49.3de | 38.8cde | 26.5b | 61.3cd | 51.5c |
| Buta fb SHW @ 4 WAS | 1.0 | 48.3a-e | 36.0c-f | 60.8bc | 62.5bcd | 44.5bcd | 21.5b | 74.3bc | 57.0bc |
| Buta fb SHW @ 8 WAS | 1.0 | 48.8a-e | 39.3b-e | 65.8b | 51.8cde | 48.3abc | 42.0ab | 78.0b | 99.0abc |
| Buta fb SHW @ 4 WAS | 1.5 | 45.3a-e | 45.0abc | 60.5bc | 51.3cde | 410cd | 25.7b | 72.3bcd | 67.7bc |
| Buta fb SHW @ 8 WAS | 1.5 | 48.8a-e | 41.3a-e | 63.8b | 62.0bcd | 45.0bc | 44.0ab | 56.5de | 110.3ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 49.5a-e | 41.3a-e | 67.5b | 56.5bcd | 48.7abc | 44.3ab | 71.7bcd | 95.7abc |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 51.3abc | 46.0ab | 61.8b | 57.8bcd | 49.3abc | 23.7b | 65.3bcd | 58.7bc |
| HWC @ 2, 4, 6 & 8 WAS | _ | 47.8a-e | 43.3a-d | 68.3b | 55.0bcd | 50.8abc | 65.3a | 64.8bcd | 127.0a |
| Weedy check | _ | 34.0f | 28.3f | 45.5c | 38.3e | 28.8e | 27.8b | 43.3e | 51.5c |
| SE ± | | 5.2 | 5.6 | 9.5 | 9.3 | 7.7 | 15.8 | 9.2 | 24.8 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Number of Tillers per Meter Square

Effects of weed control methods on number of tillers per meter square at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 22. Weed control methods resulted in significant differences on tillers per meter square at both locations and growing seasons except in 2016 raining season during 4 WAS. Application of Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ and Butachlor 1 kg a.i.ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹ recorded highest number of tillers in 2016 during 8 WAS but was at par with all of the treatment at BUK, but at DBT was significantly higher than Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 2.8 kg a.i.ha⁻¹, Butachlor 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and the weedy check.

Similarly in 2017 also Application of Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ produced statistically higher number of tillers but was at par with Butachlor 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS at BUK and with all the treatments except Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor 1 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, Butachlor 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, Butachlor 1 kg a.i.ha⁻¹ fb Solito at 0.48 kg a.i.ha⁻¹, Butachlor 1.5 kg a.i.ha⁻¹ fb Solito at 0.32 kg a.i.ha⁻¹ and the weedy check at DBT. During 8 WAS sampling the same best treatment was at par with all the treatments except Butachlor 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor 1.5 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹, Butachlor 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS Butachlor 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS and the weedy check at BUK. At DBT also the same best treatment was at par with Butachlor 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor 1.0 kg

a.i.ha⁻¹ fb Rbow at 0.030 kg a.i.ha⁻¹ Butachlor 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and the weedy check.

Leaf area (cm²)

Effects of the weed control strategies on leaf area at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 23. Significant differences were observed on leaf area at both locations in 2016 and at DBT in 2017 raining seasons. HWC at 2, 4, 6 and 8 WAS resulted in largest leaf area at BUK in 2016 raining season, however, it was statistically at par with all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS and the weedy check. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ produced the significantly largest leaf area in both raining seasons at DBT but was however at par with all the treatments except Butachlor at 1 kg a.i.ha⁻¹ fb Solito at 0.48 kg a.i.ha⁻¹ and Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS in 2016 and the weedy check in 2017.

Table 22: Number of Tillers per Meter square of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | | 2 | 2016 | | | 20: | 17 | |
|-------------------------|------------------------|-------|-------|---------|----------|----------|----------|-------------|----------|
| | a.i.ha ⁻¹) | 4W | AS | 8V | VAS | 4WA | .S | 8W <i>A</i> | AS |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 88.3 | 98.3 | 144.5ab | 140.5abc | 108.8bc | 106.0a-d | 162.5bc | 169.0a-d |
| Buta fb Orizo | 1.0 fb 4.5 | 101.8 | 97.5 | 176.5ab | 128.5a-d | 109.8bc | 102.0a-d | 189.3ab | 172.8a-d |
| Buta fb Orizo | 1.5 fb 2.8 | 106.5 | 83.3 | 167.5ab | 119.5bcd | 113.3bc | 82.3def | 169.3abc | 129.8cde |
| Buta fb Orizo | 1.5 fb 4.5 | 101.5 | 93.3 | 195.6a | 189.5a | 144.0a | 130.3a | 224.8a | 212.5a |
| Buta fb Rbow | 1.0 fb 0.025 | 93.3 | 99.0 | 161.3ab | 168.3ab | 123.3ab | 110.5a-d | 196.0ab | 158.0a-e |
| Buta fb Rbow | 1.0 fb 0.030 | 95.5 | 104.7 | 149.8ab | 162.0abc | 98.0bcd | 91.5b-e | 166.5abc | 149.5d-e |
| Buta fb Rbow | 1.5 fb 0.025 | 102.5 | 114.5 | 171.5ab | 159.8abc | 94.0bcd | 103.2a-d | 156.4bc | 164.4a-d |
| Buta fb Rbow | 1.5 fb 0.030 | 93.8 | 92.0 | 144.8ab | 163.3abc | 100.0cd | 94.5bcd | 170.0abc | 161.0a-d |
| Buta fb Solito | 1.0 fb 0.32 | 108.0 | 83.3 | 175.3a | 139.0abc | 104.8cd | 100.5a-d | 171.5abc | 156.0a-e |
| Buta fb Solito | 1.0 fb 0.48 | 96.5 | 83.3 | 140.3ab | 123.3a-d | 99.8cd | 64.0ef | 117.0cd | 102.5e |
| Buta fb Solito | 1.5 fb 0.32 | 85.0 | 96.8 | 145.3ab | 149.5abc | 98.8bcd | 96.5bcd | 149.3bcd | 158.5a-e |
| Buta fb Solito | 1.5 fb 0.48 | 96.0 | 115.0 | 149.8ab | 164.5abc | 107.0bc | 100.5a-d | 165.3abc | 160.8a-d |
| Buta fb SHW @ 4 WAS | 1.0 | 89.8 | 107.3 | 158.8ab | 148.5abc | 119.8abc | 103.3a-d | 160.3bc | 143.5d-e |
| Buta fb SHW @ 8 WAS | 1.0 | 85.8 | 80.3 | 139.3ab | 100.8cd | 104.3bc | 99.8a-d | 182.5ab | 114.8de |
| Buta fb SHW @ 4 WAS | 1.5 | 109 | 99.3 | 167.0ab | 143.5abc | 111.0bc | 108.0a-d | 159.8bc | 194.0ab |
| Buta fb SHW @ 8 WAS | 1.5 | 106 | 86.8 | 171.5ab | 139.0abc | 94.0bcd | 115.0abc | 149.8bcd | 179.5abc |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 95.8 | 92.5 | 128.3ab | 145.3abc | 91.0cd | 87.0a-f | 148.7bcd | 150.7d-e |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 105.5 | 99.3 | 156.5ab | 179.5ab | 92.3cd | 110.3a-d | 140.0bcd | 171.8a-d |
| HWC @2, 4, 6 & 8 WAS | _ | 111 | 98.0 | 175.3ab | 194.5a | 102.5bc | 122.5ab | 189.0ab | 167.5a-d |
| Weedy check | _ | 69.5 | 44.3 | 104.3ab | 67.8d | 68.5d | 60.0f | 93.0d | 124.3cde |
| SE ± | | 24.7 | 24.1 | 43.1 | 42.2 | 18.6 | 18.6 | 36.6 | 34.2 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, TLM – tillers per meter square, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Table 23: Leaf area of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | <u>Leaf ar</u> | ea (cm²) | |
|-------------------------|---------------------------------|--------|----------------|----------|--------------|
| | | | 2016 | 2 | <u> 2017</u> |
| | | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 28.4ab | 17.3ab | 28.5 | 14.6ab |
| Buta fb Orizo | 1.0 fb 4.5 | 30.2ab | 17.4ab | 28.3 | 15.9ab |
| Buta fb Orizo | 1.5 fb 2.8 | 31.3ab | 14.3ab | 33.1 | 16.3ab |
| Buta fb Orizo | 1.5 fb 4.5 | 30.3ab | 18.9a | 32.5 | 19.8a |
| Buta fb Rbow | 1.0 fb 0.025 | 26.9ab | 15.0ab | 30.2 | 18.4ab |
| Buta fb Rbow | 1.0 fb 0.030 | 27.7ab | 15.5ab | 29.4 | 17.2ab |
| Buta fb Rbow | 1.5 fb 0.025 | 31.1ab | 16.1ab | 30.4 | 15.6ab |
| Buta fb Rbow | 1.5 fb 0.030 | 32.1ab | 15.0ab | 30.3 | 18.0ab |
| Buta fb Solito | 1.0 fb 0.32 | 25.0ab | 12.8ab | 33.5 | 15.6ab |
| Buta fb Solito | 1.0 fb 0.48 | 28.2ab | 11.8b | 28.4 | 14.9ab |
| Buta fb Solito | 1.5 fb 0.32 | 29.3ab | 16.1ab | 30.0 | 18.0ab |
| Buta fb Solito | 1.5 fb 0.48 | 28.7ab | 16.6ab | 29.0 | 16.6ab |
| Buta fb SHW @ 4 WAS | 1.0 | 24.1b | 12.3ab | 29.9 | 18.6ab |
| Buta fb SHW @ 8 WAS | 1.0 | 30.8ab | 11.7b | 26.9 | 13.4ab |
| Buta fb SHW @ 4 WAS | 1.5 | 29.1ab | 16.6ab | 26.2 | 13.4ab |
| Buta fb SHW @ 8 WAS | 1.5 | 27.3ab | 15.5ab | 29.3 | 17.2ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 32.6ab | 13.0ab | 32.5 | 13.2ab |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 29.5ab | 18.2ab | 29.4 | 18.0ab |
| HWC @2, 4, 6 & 8 WAS | _ | 37.8a | 17.6ab | 27.6 | 17.9ab |
| Weedy check | _ | 25.0b | 15.3ab | 25.1 | 12.7b |
| SE ± | | 66.6 | 4.1 | 6.2 | 3.9 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Dry matter weight (g)

Effects of weed control methods on dry matter weight per plant at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 24. Significant differences were observed from the data taken on dry matter weight (DMP) in both raining seasons and locations during 4 WAS sampling and during 8 WAS at DBT in 2017 raining season. Application of Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS at BUK and Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ and also Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS at DBT gave the heaviest dry weight in 2016 at 4 WAS respectively, but however at BUK it was statistically at par with Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Rainbow at 0.025 and at 0.030 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS and the weedy check. At DBT it was statistically similar with all the treatments except the weedy check.

In 2017 during 4 WAS at BUK Butachlor application at 1.5 kg a.i.ha⁻¹ fb Rbow at 0.030 kg a.i.ha⁻¹ recorded the heaviest DMP but was at par with all the treatments except Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and the weedy check. At DBT in the same period however, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ resulted in the heaviest DMP, but was at par with all the treatments except Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹ and the weedy check. During 8WAS sampling at BUK no significant differences was noted. But at DBT Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS was the heaviest though it was similar with all other treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and the weedy check.

Table 24: Dry Matter Weight of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | | | 2016 | | | 20 |)17 | |
|-------------------------|------------------------|--------|-------|------|------|--------|--------|------|--------|
| | a.i.ha ⁻¹) | 4WA | 5 | 8 | WAS | 4WA | S | 8 V | VAS |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 6.0bc | 8.3ab | 16.3 | 15.5 | 8.3abc | 12.0ab | 15.3 | 7.9ab |
| Buta fb Orizo | 1.0 fb 4.5 | 5.0c | 8.3ab | 15.5 | 14.8 | 6,5abc | 9.7ab | 16.5 | 10.5ab |
| Buta fb Orizo | 1.5 fb 2.8 | 6.8abc | 7.3ab | 16.3 | 14.8 | 7.5abc | 10.7b | 18.8 | 7.8ab |
| Buta fb Orizo | 1.5 fb 4.5 | 7.5abc | 10.0a | 14.0 | 16.8 | 7.3abc | 16.7a | 18.5 | 18.3ab |
| Buta fb Rbow | 1.0 fb 0.025 | 5.8bc | 8.0ab | 19.3 | 14.8 | 7.3abc | 11.3ab | 20.5 | 12.5ab |
| Buta fb Rbow | 1.0 fb 0.030 | 7.0bc | 7.8ab | 19.3 | 15.5 | 8.0abc | 10.7ab | 21.5 | 12.5ab |
| Buta fb Rbow | 1.5 fb 0.025 | 8.0abc | 7.8ab | 14.8 | 14.8 | 7.6abc | 10.0ab | 21.4 | 13.0ab |
| Buta fb Rbow | 1.5 fb 0.030 | 6.5abc | 8.8ab | 20.0 | 17.5 | 9.5a | 10.0ab | 20.5 | 10.5ab |
| Buta fb Solito | 1.0 fb 0.32 | 7.3abc | 7.0ab | 16.0 | 16.0 | 8.5abc | 9.5ab | 14.5 | 6.9ab |
| Buta fb Solito | 1.0 fb 0.48 | 7.3abc | 7.3ab | 20.3 | 16.3 | 6.5abc | 9.7ab | 14.5 | 9.9ab |
| Buta fb Solito | 1.5 fb 0.32 | 7.0abc | 7.3ab | 16.5 | 13.5 | 7.3abc | 9.3ab | 15.5 | 12.4ab |
| Buta fb Solito | 1.5 fb 0.48 | 7.3abc | 8.8ab | 15.0 | 15.0 | 7.8abc | 9.0ab | 20.8 | 17.5ab |
| Buta fb SHW @ 4 WAS | 1.0 | 5.0c | 6.8ab | 16.3 | 13.5 | 6.8ab | 9.5ab | 20.8 | 14.5ab |
| Buta fb SHW @ 8 WAS | 1.0 | 10.3a | 7.0ab | 22.3 | 15.3 | 8.0abc | 13.0ab | 16.8 | 3.5b |
| Buta fb SHW @ 4 WAS | 1.5 | 7.8abc | 7.3ab | 20.5 | 13.3 | 6.8abc | 9.3ab | 16.3 | 13.7ab |
| Buta fb SHW @ 8 WAS | 1.5 | 5.5c | 8.8ab | 18.5 | 15.8 | 5.8bc | 14.0ab | 17.8 | 8.0ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 8.3abc | 9.3a | 15.8 | 15.3 | 8.0abc | 14.7ab | 18.7 | 6.1ab |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 7.5abc | 8.0ab | 16.8 | 16.5 | 6.0bc | 9.0ab | 18.5 | 19.3a |
| HWC @2, 4, 6 & 8 WAS | _ | 9.5ab | 8.0ab | 17.8 | 16.5 | 7.0abc | 14.0ab | 19.0 | 6.3ab |
| Weedy check | _ | 4.8c | 5.8b | 13.3 | 13.8 | 5.0c | 6.3b | 15.8 | 3.3b |
| SE ± | | 2.31 | 1.99 | 4.93 | 3.20 | 1.92 | 4.00 | 4.1 | 8.49 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, DMP – dry matter per plant, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta – Butachlor

Crop vigor score

Effects of weed control methods on crop vigor score (CVS) at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 25. Significant differences on the performance of weed control strategies were recorded on CVS in both locations and raining seasons except at DBT during both sampling periods in 2017 raining season. The highest crop vigor score in 2016 raining season was obtained from the application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ during 4 and 8 WAS at BUK and DBT respectively, while Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow at 0.320 kg a.i.ha⁻¹ had the statistically highest CVS at DBT during 4 WAS in the same year. The treatments were however at par with Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹ and the weedy check at BUK and with Butachlor at 1 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹ and Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS at DBT. The best treatment at DBT during 8 WAS was at par with only HWC at 2, 4, 6 & 8 WAS. In 2017 raining season at BUK during 8 WAS application of Butachlor at 1 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS was the best though at par with Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6 & 8 WAS. The weedy check had the least CVS in all the growing seasons and the experimental sites.

Table 25: Crop Vigor Score of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | | 2016 | | | 2 | 017 | |
|-------------------------|------------------------------------|--------|--------|------|----------|--------|------|--------|------------|
| | a.i.iia) | 4 WAS | | 8 WA | <u>S</u> | 4 WAS | | 8\ | <u>WAS</u> |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 4.5cd | 3.8bc | 5.8a | 5.0bcd | 4.0abc | 5.5 | 5.0c-g | 4.5 |
| Buta fb Orizo | 1.0 fb 4.5 | 6.0abc | 5.5ab | 5.8a | 6.3bc | 4.5abc | 6.0 | 4.8c-g | 5.0 |
| Buta fb Orizo | 1.5 fb 2.8 | 6.0abc | 5.8ab | 6.0a | 6.3bc | 4.5abc | 4.3 | 6.3a-e | 7.5 |
| Buta fb Orizo | 1.5 fb 4.5 | 7.3a | 5.9abc | 5.3a | 8.0a | 6.3a | 5.0 | 7.5ab | 7.0 |
| Buta fb Rbow | 1.0 fb 0.025 | 6.0abc | 4.3abc | 4.3a | 5.5bcd | 4.3abc | 4.3 | 5.5b-g | 5.0 |
| Buta fb Rbow | 1.0 fb 0.030 | 5.3bc | 5.0abc | 5.8a | 5.5bcd | 6.0ab | 4.3 | 4.5d-g | 6.0 |
| Buta fb Rbow | 1.5 fb 0.025 | 63ab | 4.8abc | 5.5a | 6.0bcd | 5.0abc | 4.5 | 5.6b-g | 5.3 |
| Buta fb Rbow | 1.5 fb 0.030 | 5.8abc | 3.8bc | 5.5a | 5.3bcd | 4.5abc | 4.0 | 5.3b-g | 5.3 |
| Buta fb Solito | 1.0 fb 0.32 | 6.0abc | 6.3a | 5.0a | 6.3bc | 5.5ab | 3.8 | 3.5gh | 5.5 |
| Buta fb Solito | 1.0 fb 0.48 | 6.0abc | 5.3ab | 3.8a | 5.3bcd | 5.5ab | 5.7 | 5.0c-g | 5.7 |
| Buta fb Solito | 1.5 fb 0.32 | 5.8abc | 4.5abc | 5.5a | 5.3bcd | 5.8ab | 4.8 | 4.3efg | 3.5 |
| Buta fb Solito | 1.5 fb 0.48 | 6.5ab | 4.8abc | 6.0a | 5.5bcd | 5.0abc | 5.0 | 6.0b-f | 3.5 |
| Buta fb SHW @ 4 WAS | 1.0 | 6.0abc | 4.3abc | 4.8a | 5.0bcd | 2.8c | 6.5 | 5.5b-g | 5.0 |
| Buta fb SHW @ 8 WAS | 1.0 | 6.3ab | 5.8ab | 5.0a | 4.8cd | 3.0c | 3.0 | 3.8fgh | 6.0 |
| Buta fb SHW @ 4 WAS | 1.5 | 6.5ab | 4.8abc | 5.5a | 6.0bcd | 3.8bc | 5.3 | 6.0b-f | 6.7 |
| Buta fb SHW @ 8 WAS | 1.5 | 6.5ab | 5.3ab | 5.8a | 5.3bcd | 5.5ab | 5.3 | 4.0efg | 6.3 |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 6.0abc | 5.3ab | 4.3a | 4.3d | 3.0c | 6.0 | 8.3a | 5.7 |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 5.8abc | 4.0bc | 4.8a | 4.8cd | 4.3abc | 4.3 | 6.8a-d | 5.7 |
| HWC @ 2, 4, 6 & 8 WAS | _ | 5.8abc | 5.0abc | 6.3a | 6.8ab | 3.8bc | 6.0 | 7.0abc | 5.0 |
| Weedy check | _ | 3.5d | 3.0abc | 1.8b | 1.8e | 3.0c | 4.0 | 1.8h | 5.0 |
| SE ± | | 0.89 | 1.21 | 1.52 | 1.13 | 1.34 | 2.01 | 1.42 | 2.44 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, CVS – crop vigor score, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

^{*}CVS = Using a scale of 1-9 where 1 represented completely dead plants and 9 represented the most vigorous plants.

Leaf area index (LAI)

Effects of weed control methods on laef area index (LAI) at BUK and DBT during 2016 and 2017 growing seasons is presented in Table 26. Significant differences on the performance of weed control strategies were recorded on LAI at both locations and raining seasons. HWC at 2, 4, 6 & 8 WAS and Butachlor applied at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS recorded the highest LAI at BUK and DBT, respectively, in 2016 raining season. It is however, at par with all of the treatments at BUK except the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹ and the weedy check that had the lowest LAI. At DBT in the same year, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS recorded the highest LAI but was at par with all the treatments except Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 2.8 kg a.i.ha⁻¹, Butachlor 1 kg a.i.ha⁻¹ fb Rbow 0.320 kg a.i.ha⁻¹, Butachlor 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and HWC at 2, 4, 6 and 8 WAS.

In 2017 similarly the highest leaf area index was recorded by the application of Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ at BUK, but at DBT, it was Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS at that position, these treatment were however, at par with Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.025 kg a.i.ha⁻¹ and Butachlor at 1.0 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹ at BUK and with all the treatments except the weedy check at DBT.

Crop growth rate (g/m²/wk)

Result on crop growth rate (CGR) for BUK and DBT in 2016 and 2017 growing seasons is presented in Table 26. Weed control strategies recorded significant differences on crop growth rate only at BUK in 2017 raining season. Application of Butachlor 1.5 kg

a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ gave significantly higher CGR of rice than the weedy check but was statistically at par with all other weed control treatments.

Table 26: Leaf area Index (LAI) and Crop Growth Rate (CGR) of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | | | 2016 | | | 2 | 017 | |
|-------------------------|------------------------|------------------|--------------|------|------------|---------------|-----------|-------|-----------|
| | a.i.ha ⁻¹) | <u>Leaf area</u> | <u>index</u> | | rowth rate | <u>Leaf a</u> | rea index | | owth rate |
| | | | | | m²/wk) | | | | g/m²/wk) |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 2.5b | 1.7abc | 4.2 | 3.0 | 3.1abc | 3.5ab | 4.7ab | 9.2 |
| Buta fb Orizo | 1.0 fb 4.5 | 3.1ab | 1.4a-e | 4.8 | 3.0 | 3.3ab | 2.2ab | 4.3ab | 6.8 |
| Buta fb Orizo | 1.5 fb 2.8 | 3.1ab | 1.0cde | 6.0 | 3.0 | 3.3ab | 3.9ab | 4.8ab | 8.4 |
| Buta fb Orizo | 1.5 fb 4.5 | 2.6ab | 1.8ab | 6.0 | 3.6 | 3.9a | 1.8ab | 5.9a | 10.6 |
| Buta fb Rbow | 1.0 fb 0.025 | 2.6ab | 1.2a-e | 3.0 | 2.4 | 2.9abc | 3.3ab | 5.6ab | 3.2 |
| Buta fb Rbow | 1.0 fb 0.030 | 2.7ab | 1.5a-e | 5.4 | 3.6 | 2.9abc | 2.3ab | 5.8ab | 7.2 |
| Buta fb Rbow | 1.5 fb 0.025 | 3.1ab | 1.8ab | 6.0 | 3.0 | 2.4c | 2.3ab | 4.8ab | 6.0 |
| Buta fb Rbow | 1.5 fb 0.030 | 2.9ab | 1.5a-e | 6.0 | 3.6 | 3.1abc | 2.2ab | 4.7ab | 5.6 |
| Buta fb Solito | 1.0 fb 0.32 | 2.8ab | 1.1b-e | 3.6 | 3.6 | 3.4ab | 2.2ab | 4.1ab | 9.2 |
| Buta fb Solito | 1.0 fb 0.48 | 2.8ab | 1.4a-e | 5.4 | 3.6 | 1.8c | 2.0ab | 5.6ab | 6.8 |
| Buta fb Solito | 1.5 fb 0.32 | 2.6ab | 1.4a-e | 4.2 | 2.4 | 2.7abc | 2.2ab | 3.5ab | 5.6 |
| Buta fb Solito | 1.5 fb 0.48 | 2.7ab | 1.6a-d | 3.6 | 2.4 | 3.2abc | 1.2ab | 5.6ab | 2.4 |
| Buta fb SHW @ 4 WAS | 1.0 | 2.6ab | 1.1b-e | 4.8 | 3.0 | 3.2abc | 1.7ab | 5.1ab | 1.6 |
| Buta fb SHW @ 8 WAS | 1.0 | 2.6ab | 0.7e | 5.4 | 3.6 | 3.0abc | 3.0ab | 3.7ab | 8.0 |
| Buta fb SHW @ 4 WAS | 1.5 | 3.0ab | 1.3a-e | 5.4 | 3.0 | 2.6abc | 1.4ab | 4.0ab | 2.0 |
| Buta fb SHW @ 8 WAS | 1.5 | 3.0ab | 1.3a-e | 5.4 | 3.0 | 2.6abc | 3.9ab | 5.1ab | 8.8 |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 2.8ab | 1.0b-e | 3.0 | 3.6 | 2.9abc | 4.8a | 4.5ab | 6.0 |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 3.4ab | 2.0a | 4.2 | 3.0 | 2.7abc | 1.8ab | 5.3ab | 12 |
| HWC @2, 4, 6 & 8 WAS | _ | 4.4a | 1.7abc | 3.6 | 3.6 | 3.1abc | 2.0ab | 5.1ab | 12 |
| Weedy check | _ | 1.8b | 1.0b-e | 3.6 | 3.0 | 2.9abc | 2.4ab | 3.1b | 5.6 |
| SE ± | - | 1.14 | 0.52 | 1.80 | 1.22 | 0.85 | 1.62 | 1.53 | 6.42 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta – Butachlor, wk - week

4.1.3 Yield and Yield Components

Number of panicles per meter square (m⁻²)

Result on number of panicles per meter square for BUK and DBT in 2016 and 2017 raining saesons is presented in Table 27. Significant differences (P ≤ 0.05) were recorded from both locations and raining seasons. Application of Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow 0.025 kg a.i.ha⁻¹ produced the significantly highest number of panicles at BUK and DBT in 2016 raining season, respectively. It was however, statistically at par with all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow 30 g a.i.ha⁻¹ and weedy check at BUK, and all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS and the weedy check at DBT.

In 2017 raining season application of Butachlor at 1 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS at BUK had the highest number of panicles but was at par with all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Rbow at 0.030 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW 4 & 8 WAS and the weedy check. At DBT in the same year application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ produced the highest number of tillers. Though, it was at par with all the

treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8WAS and the weedy check.

Panicles length (cm)

Effect of weed control methods on panicles length per plant at BUK and DBT in 2016 and 2017 raining saesons is presented in Table 27. Effect of weed control methods on panicles length per plant recorded significant differences (P ≤ 0.05) at both locations and raining seasons. The longest panicles were recorded by the treatments that recieved the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ at BUK in 2016 raining season. However, it was significantly higher than Butachlor at 1.0 kg a.i. ha⁻¹ fb Rainbow at 0.030 kg a.i. ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb SHW at 8 WAS and the weedy check. Application of Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ at DBT had the longest panicles, but it was statistically similar with Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.0 kg a.i. ha⁻¹ fb SHW at 4 & 8 WAS and the weedy check.

In 2017 at BUK, HWC at 2,4,6 & 8 WAS produced the longest panicle but was at par with all the treatments except Butachlor at 1.0 kg a.i. ha⁻¹ fb Rbow at 0.030 kg a.i.ha⁻¹,Butachlor at 1.0 kg a.i. ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i. ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS and Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS recorded the longest panicle but was at par with all the treatments except the weedy check at DBT in 2017.

Table 27: Number of Panicles per Meter Square and Panicles Length (cm) of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | | | 2016 | | | 20 | 17 | |
|-------------------------|------------------------|------------|-------------------------|------------|---------------|-------------|-------------------------|------------|-----------|
| | a.i.ha ⁻¹) | No.of pani | cles per m ² | Panicles l | ength(cm) | No. of Pani | cles per m ² | Panicles l | ength(cm) |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 58.8abc | 107.5ab | 15.5abc | 16.0ab | 69.5bcd | 86.3abc | 17.3ab | 12.0ab |
| Buta fb Orizo | 1.0 fb 4.5 | 98.5abc | 67.5bcd | 20.8a | 15.5ab | 54.0cd | 83.0abc | 18.8ab | 14.7ab |
| Buta fb Orizo | 1.5 fb 2.8 | 73.3abc | 55.5cd | 16.8abc | 17.0ab | 72.3bcd | 100.8ab | 18.0ab | 13.3ab |
| Buta fb Orizo | 1.5 fb 4.5 | 80.9abc | 87.0a-d | 20.3ab | 21 .3a | 116.5ab | 126.0a | 19.3ab | 19.0a |
| Buta fb Rbow | 1.0 fb 0.025 | 58.3abc | 80.3a-d | 18.5ab | 15.8ab | 58.8d | 90.5abc | 16.8ab | 14.0ab |
| Buta fb Rbow | 1.0 fb 0.030 | 49.8bc | 99.5abc | 14.5bc | 17.0ab | 68.0cd | 100.3ab | 15.5b | 14.7ab |
| Buta fb Rbow | 1.5 fb 0.025 | 70.5abc | 115.8a | 18.3abc | 18.5ab | 62.2cd | 96.2ab | 19.6ab | 15.0ab |
| Buta fb Rbow | 1.5 fb 0.030 | 65.5abc | 105.8ab | 15.5abc | 16.5ab | 87.5a-d | 85.3abc | 18.3ab | 10.7ab |
| Buta fb Solito | 1.0 fb 0.32 | 68.0abc | 64.0bcd | 15.8abc | 16.3ab | 62.5cd | 77.5abc | 15.3b | 10.3ab |
| Buta fb Solito | 1.0 fb 0.48 | 93.5abc | 86.3a-d | 19.8abc | 16.3ab | 72.3abc | 46.0c | 15.0b | 14.0ab |
| Buta fb Solito | 1.5 fb 0.32 | 101.3ab | 76.3a-d | 16.0abc | 14.5b | 82.5a-d | 96.5ab | 18.8ab | 15.0ab |
| Buta fb Solito | 1.5 fb 0.48 | 77.3abc | 101.5abc | 14.5bc | 16.3ab | 85.0a-d | 103.5ab | 18.5ab | 20.0a |
| Buta fb SHW @ 4 WAS | 1.0 | 74.3abc | 98.0abc | 18.3abc | 19.3ab | 77.3a-d | 81.0abc | 16.3b | 15.5ab |
| Buta fb SHW @ 8 WAS | 1.0 | 67.8abc | 60.3bcd | 17.5abc | 16.0ab | 94.8a-d | 55.0bc | 17.3b | 10.3ab |
| Buta fb SHW @ 4 WAS | 1.5 | 65.0abc | 70.0a-d | 17.8abc | 16.8ab | 80.8a-d | 95.5abc | 23.0a | 20.7a |
| Buta fb SHW @ 8 WAS | 1.5 | 67.5ab | 61.5bcd | 14.0c | 12.3b | 81.8a-d | 90.0abc | 19.5ab | 8.0ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 107.5a | 96.5abc | 19.3abc | 14.3b | 120.0a | 114.0a | 18.3ab | 7.8ab |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 57.3abc | 107.3ab | 20.3ab | 15.5ab | 70.5bcd | 119.3a | 19.3ab | 15.7ab |
| HWC @ 2, 4, 6 & 8 WAS | | 68.8abc | 95.3abc | 17.8abc | 15.8ab | 109.3abc | 109.8a | 20.3a | 6.0ab |
| Weedy check | _ | 42.2c | 45.8d | 14.5bc | 1.5b | 51.5d | 58.3bc | 18.0ab | 4.0b |
| SE ± | _ | 33.10 | 27.61 | 3.412 | 3.90 | 28.02 | 29.61 | 3.90 | 6.95 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC = Hoe weeded control, Buta - Butachlor

Panicles weight per plant (g)

Effect of weed control methods on panicles weight per plant at BUK and DBT in 2016 and 2017 raining saesons is presented in Table 28. Panicles weight was significantly $(P \le 0.05)$ affected by weed control methods at both locations and raining seasons except at BUK in 2017 where no significant difference was recorded. Treatment that recieved Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS produced the heaviest panicles at BUK in 2016, but at DBT it was by HWC at 2, 4, 6 & 8 WAS. This best treatment(Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS) was at par with Butachlor at 1.0 kg a.i. ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Rbow at 0.025 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i. ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.0 kg a.i. ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.5 kg a.i. ha⁻¹ fb SHW at 4 WAS and the HWC at BUK. At DBT however, it was at par with all the treatments except Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹ and the weedy check which had the lightest panicle. In 2017 at BUK no significant differences was recorded. At DBT treatment that recieved Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ had the heaviest panicle, while the rest of the treatment were statistically lighter and the Weedy check recorded the lightest panicles (Table 28).

1000-grain weight (g)

Effect of weed control methods on thousand grain weight at BUK and DBT in 2016 and 2017 raining saesons is presented in Table 28. It had been shown that there was significant differences ($P \le 0.05$) among the means recorded at all the locations and

raining seasons. At BUK in 2016 raining saeson the heaviest 1000-grain weight was recorded by treatment that received application of Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS but was at par with all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.025 kg a.i.ha⁻¹ ¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹ and the weedy check. At DBT it was Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS that occupied the first position, but was at par with all the treatments except the weedy check. In 2017 growing season, application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ recorded the significantly heaviest 1000grain weight at both locations, but it was statistically the same with Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW 8 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW 4 & 8 WAS and the HWC at 2, 4, 6 & 8 WAS at BUK. At DBT however, it was only at par with Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹ and Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹ ¹. The weedy check recorded the lightest 1000-grain weight at both locations in 2017.

Table 28: Panicles Weight per plant and 1000-Grain Weight of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg | | | 2016 | | | 2 | 2017 | |
|-------------------------|------------------------|-------------------|--------|------|----------------------|-------------------|--------|-------------------|------|
| | a.i.ha ⁻¹) | | | | | | | | |
| | | <u>Panicles v</u> | | | <u>in weight (g)</u> | <u>Panicles v</u> | | <u>1000-grain</u> | |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 3.8b | 4.3a-d | 30ab | 33ab | 4.3 | 4.5bcd | 28c | 33bc |
| Buta fb Orizo | 1.0 fb 4.5 | 5.0ab | 4.3a-d | 33ab | 30ab | 5.3 | 5.0bc | 30bc | 33bc |
| Buta fb Orizo | 1.5 fb 2.8 | 5.0ab | 3.0cd | 30ab | 30ab | 5.5 | 4.0b-e | 38ab | 40ab |
| Buta fb Orizo | 1.5 fb 4.5 | 5.8ab | 5.0ab | 33ab | 35ab | 5.3 | 7.3a | 40a | 42a |
| Buta fb Rbow | 1.0 fb 0.025 | 4.8ab | 5.0ab | 35ab | 33ab | 5.0 | 4.0b-e | 30bc | 30c |
| Buta fb Rbow | 1.0 fb 0.030 | 3.8b | 3.8a-d | 28b | 30ab | 4.0 | 4.0b-e | 30bc | 30c |
| Buta fb Rbow | 1.5 fb 0.025 | 5.0ab | 4.8abc | 28b | 33ab | 4.6 | 4.8b-e | 30bc | 34bc |
| Buta fb Rbow | 1.5 fb 0.030 | 3.5b | 4.3a-d | 33ab | 33ab | 5.8 | 4.0b-e | 30bc | 40ab |
| Buta fb Solito | 1.0 fb 0.32 | 4.5b | 3.8a-d | 30ab | 33ab | 4.0 | 3.3cde | 30bc | 30c |
| Buta fb Solito | 1.0 fb 0.48 | 5.0b | 3.8a-d | 28b | 35ab | 4.8 | 3.7b-e | 30bc | 33bc |
| Buta fb Solito | 1.5 fb 0.32 | 4.0b | 3.0cd | 30ab | 30ab | 6.3 | 3.0b-e | 30bc | 30c |
| Buta fb Solito | 1.5 fb 0.48 | 3.5b | 3.8a-d | 28b | 35ab | 5.5 | 4.5bcd | 30bc | 28c |
| Buta fb SHW @ 4 WAS | 1.0 | 5.0ab | 4.8abc | 33ab | 38ab | 5.5 | 5.0bc | 30bc | 33bc |
| Buta fb SHW @ 8 WAS | 1.0 | 5.5ab | 3.8a-d | 33ab | 33ab | 6.0 | 3.0de | 38ab | 28c |
| Buta fb SHW @ 4 WAS | 1.5 | 5.8ab | 3.8a-d | 33ab | 40a | 5.5 | 5.3b | 30bc | 30c |
| Buta fb SHW @ 8 WAS | 1.5 | 4.3b | 3.3bcd | 33ab | 35ab | 5.3 | 3.7b-e | 33abc | 33bc |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 7.3a | 3.8a-d | 40a | 33ab | 5.3 | 3.7b-e | 33abc | 30bc |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 4.5b | 4.5a-d | 33ab | 38ab | 4.5 | 3.7b-e | 30bc | 33bc |
| HWC @ 2, 4, 6 & 8 WAS | _ | 5.0ab | 5.3a | 33ab | 35ab | 5.8 | 3.0de | 38ab | 35bc |
| Weedy check | _ | 3.3b | 2.8d | 28b | 29b | 4.5 | 2.3e | 20d | 20d |
| SE ± | _ | 1.45 | 1.14 | 6.73 | 5.81 | 1.68 | 0.85 | 5.01 | 4.72 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Paddy yield (kg ha⁻¹)

Effect of weed control methods on paddy yield of upland rice at BUK and DBT in 2016 and 2017 raining saesons is presented in Table 29. Paddy yield was significantly affected (P ≤ 0.05) by weed control strategies at both locations and raining seasons. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ produced the the highest paddy yield at BUK in both seasons and at DBT in 2016 raining seasons. at DBT in 2017 raining season application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹ was at par with the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹. The next higher paddy yield position was occupied by all the treatments except the application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.025 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Rainbow at 0.320 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹ and the weedy check which had the least at BUK. The weedy check had the lowest paddy yield at both locations

Similarly in 2017 raining saeson at BUK the significantly highest paddy yield treatment (Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹) was at par with the application of Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 8 WAS and the HWC at 2, 4, 6, & 8 WAS. The result further indicated that at DBT during 2017 raining season the statistically highest paddy yield treatment (Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹) to be at par with treatments that received the application of Butachlor at 1.5 kg a.i. ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor

at 1.0 kg a.i. ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, Butachlor at 1 kg a.i. ha⁻¹ fb Solito at 0.320 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and HWC at 2, 4, 6, & 8 WAS. The weedy check had the lowest paddy yield.

Stover yield (kgha⁻¹)

Effect of weed control methods on stover yield in kilogram per hactare at BUK and DBT in 2016 and 2017 raining saesons is presented in Table 29. There were no significant differences in the stover yield of all the treatments evaluated except at DBTin 2017 rainning season. The highest stover yield at DBT in 2017 was recorded by HWC at 2, 4, 6 & 8 WAS, but was at par with all the treatments except Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb Solito at 0.480 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and the weedy check

.

Table 29: Stover and Paddy Yield of Upland Rice as Affected by Weed Control Strategies at BUK and DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | 2 | 016 | | | 201 | .7 | |
|-------------------------|------------------------------------|------------|--------------------------|------------|---------------------------|-----------|----------------------------|-----------|----------------------------|
| | a.i.iia) | Paddy yiel | d (kg ha ⁻¹) | Stover yie | ld (kg ha ⁻¹) | Paddy yie | eld (kg ha ⁻¹) | Stover yi | eld (kg ha ⁻¹) |
| | | BUK | DBT | BUK | DBT | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 1419b-f | 1952bcd | 667 | 448 | 1428bc | 1683bcd | 247 | 1463ab |
| Buta fb Orizo | 1.0 fb 4.5 | 1507b-f | 1790bcd | 759 | 538 | 1304bc | 1640bcd | 558 | 792b |
| Buta fb Orizo | 1.5 fb 2.8 | 1783b | 1599cde | 999 | 734 | 1722bc | 1956abc | 903 | 830b |
| Buta fb Orizo | 1.5 fb 4.5 | 2111a | 2470a | 1040 | 935 | 2001a | 2327a | 848 | 1835ab |
| Buta fb Rbow | 1.0 fb 0.025 | 1456b-f | 1678b-e | 604 | 801 | 1474bc | 1768bc | 825 | 815b |
| Buta fb Rbow | 1.0 fb 0.030 | 1558b-f | 2107ab | 675 | 821 | 1514bc | 1909abc | 681 | 1347ab |
| Buta fb Rbow | 1.5 fb 0.025 | 1347c-f | 1895bcd | 766 | 826 | 1435bc | 1620bcd | 855 | 925ab |
| Buta fb Rbow | 1.5 fb 0.030 | 1257ef | 2029bc | 951 | 796 | 1533bc | 1840abc | 911 | 1554ab |
| Buta fb Solito | 1.0 fb 0.32 | 1457b-f | 1586cde | 731 | 548 | 1533bc | 1809abc | 723 | 1335ab |
| Buta fb Solito | 1.0 fb 0.48 | 1302def | 1558cde | 641 | 892 | 1384bc | 1589bcd | 630 | 1050ab |
| Buta fb Solito | 1.5 fb 0.32 | 1372c-f | 1805bcd | 405 | 746 | 1688abc | 1741bcd | 887 | 949ab |
| Buta fb Solito | 1.5 fb 0.48 | 1294ef | 1790bcd | 641 | 651 | 1697abc | 1951abc | 854 | 658b |
| Buta fb SHW @ 4 WAS | 1.0 | 1497b-f | 1834bcd | 728 | 865 | 1690abc | 1449cd | 941 | 566b |
| Buta fb SHW @ 8 WAS | 1.0 | 1726bc | 1526de | 1038 | 840 | 1715abc | 1643bcd | 838 | 1450ab |
| Buta fb SHW @ 4 WAS | 1.5 | 1723bc | 1608cde | 653 | 793 | 1470bc | 2020ab | 687 | 1262ab |
| Buta fb SHW @ 8 WAS | 1.5 | 1642b-e | 1549cde | 600 | 818 | 1577abc | 1648bcd | 626 | 1495ab |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 1711bc | 1503bcd | 733 | 660 | 1455bc | 1958abc | 841 | 1380ab |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 1535b-f | 1972bcd | 771 | 1090 | 1400bc | 1912abc | 580 | 766b |
| HWC @ 2, 4, 6 & 8 WAS | _ | 1691bcd | 1902bcd | 538 | 739 | 1581abc | 1883abc | 718 | 2167a |
| Weedy check | _ | 1190f | 1214e | 531 | 923 | 1238c | 1226d | 358 | 750b |
| SE ± | | 230 | 290 | 457 | 350 | 273 | 315 | 449 | 600 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Harvest index (%)

The effect of weed control methods on harvest index (HI) at BUK and DBT in 2016 and 2017 raining seasons is presented in Table 30. The result indicated significant differences (P ≤ 0.05) at both locations and growing seasons except for BUK in 2016 where no significant differences were recorded. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i. ha⁻¹ and Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i. ha⁻¹ produced the highest harvest index at DBT in 2016 but was at par with all the treatments except the weedy control. In 2017 also the highest HI was recoeded by the application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo at 4.5 kg a.i. ha⁻¹ but was at par with all of the treatments except Butachlor at 1.0 kg a.i. ha⁻¹ fb SHW at 4 and 8 WAS at BUK, and except Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i. ha⁻¹, Butachlor at 1.5 kg a.i. ha⁻¹ fb SHW at 4 WAS, Butachlor at 1.5 kg a.i. ha⁻¹ fb SHW at 8 WAS and the weedy check at DBT.

Table 30: Harvest Index of Upland Rice as Affected by Weed Control Strategies at BUK and

DBT in 2016 and 2017 Raining Seasons

| Treatments | Rate (kg a.i.ha ⁻¹) | | Harvest | index (%) | |
|-------------------------|---------------------------------|-------|---------|-----------|------------|
| | | | 2016 | 20 | <u> 17</u> |
| | | BUK | DBT | BUK | DBT |
| Buta fb Orizo | 1.0 fb 2.8 | 70.9 | 72.9ab | 71.6ab | 67.0abc |
| Buta fb Orizo | 1.0 fb 4.5 | 67.5 | 77.3a | 71.6ab | 74.8abc |
| Buta fb Orizo | 1.5 fb 2.8 | 65.1 | 68.0ab | 67.8ab | 74.1abc |
| Buta fb Orizo | 1.5 fb 4.5 | 78.2 | 80.1a | 85.1a | 80.3a |
| Buta fb Rbow | 1.0 fb 0.025 | 62.8 | 66.8ab | 68.1ab | 68.2abc |
| Buta fb Rbow | 1.0 fb 0.030 | 74.5 | 72.5ab | 70.5ab | 72.9abc |
| Buta fb Rbow | 1.5 fb 0.025 | 66.4 | 70.6ab | 65.4ab | 70.6abc |
| Buta fb Rbow | 1.5 fb 0.030 | 61.5 | 73.0ab | 64.9ab | 61.8bc |
| Buta fb Solito | 1.0 fb 0.32 | 69.1 | 74.9ab | 68.6ab | 71.8abc |
| Buta fb Solito | 1.0 fb 0.48 | 71.2 | 65.0ab | 69.1ab | 70.5abc |
| Buta fb Solito | 1.5 fb 0.32 | 77.7 | 71.0ab | 66.8ab | 77.2ab |
| Buta fb Solito | 1.5 fb 0.48 | 67.7 | 74.7ab | 67.4ab | 72.6abc |
| Buta fb SHW @ 4 WAS | 1.0 | 67.4 | 69.1ab | 65.5ab | 69.5abc |
| Buta fb SHW @ 8 WAS | 1.0 | 63.4 | 64.6ab | 69.0ab | 74.0abc |
| Buta fb SHW @ 4 WAS | 1.5 | 74.4 | 67.8ab | 68.6ab | 62.6bc |
| Buta fb SHW @ 8 WAS | 1.5 | 76.3 | 64.6ab | 74.9ab | 61.5bc |
| Buta fb SHW @ 4 & 8 WAS | 1.0 | 71.1 | 73.2ab | 64.3b | 72.2abc |
| Buta fb SHW @ 4 & 8 WAS | 1.5 | 67.6 | 65.3ab | 71.1ab | 73.6abc |
| HWC @ 2, 4, 6 & 8 WAS | _ | 75.2 | 73.0ab | 70.3ab | 66.3abc |
| Weedy check | _ | 65.8 | 59.6b | 77.2ab | 60.4c |
| SE ± | | 12.82 | 10.21 | 11.80 | 9.60 |

Means with the same letter in the same column are not significantly different $P \le 0.05$ using SNK, WAS – Week after sowing, BUK – Bayero University Kano, DBT – Thomas dam Dambatta, SHW – supplementary hoe weeding, HWC= Hoe weeded control, Buta - Butachlor

Matrix of correlation and path coefficient analysis between grain yield of rice and other parameters

Matrix of correlation analysis for BUK in 2016 raining season is presented in Table 31. It indicated significant and positive correlation between grain yield and some growth parameters like plant height (r = 0.511**), dry matter per plant (r = 0.440**), tillers per meter square (r = 0.247*) and leaf area index (r = 0.361**). There was a highly significant negative correlation between grain yield and weed cover score (r = -0.5777**) and also weed dry weight (r= -0.0361**) but positive correlation with weed control efficiency. Panicles weight (r = 0.690**) was significant and positively correlated with grain yield while panicles per meter square recorded positive but non significant relationship with grain yield. Growth variables like plant height, dry matter weight and tillers per meter square were all positevly correlated among themselves. Yield components also displayed significant and positive associations with each other, so also with growth attributes, except panicles number per meter square which was not significantly correlated. Weed data like weed cover score and weed dry weight recorded significant but negative correlation with the growth and yield characters, but positively associated with each other, the only exception is weed control efficiency which was positively correlated with growth and yield attributes but negative with weed cover score and dry weight.

Analysis of individual and combined contribution of some growth and yield characters by path coefficient on paddy yield is presented in Table 34 and 35. It could be observed that at BUK in 2016 raining season, the highest direct contribution to paddy yield came from the panicles number pre m² and panicles weight with 21.759% and

10.606%, respectively. Combined contribution of plant height via panicles weight was 4.4297% and for leaf area index via panicles weight was 3.0085%. However, when the individual contributions of dry matter weight and panicles number per meter square were partitioned it indicated negligible percentage contribution of 0.689% and 0.384%, respectively. Similarly the highest direct contribution among the parameters observed came from panicles weight with 31.356% so also its combined contributions was 8.031%, and as such the total percentage contribution of panicles weight was 39.388 percent. The total residual effect was 41.11%.

Result of correlation coefficient for DBT in 2016 raining season is presented in Table 32. It indicated significant and positive correlation between grain yield and some growth parameters like plant height (r = 0.539**), dry matter per plant (r = 0.623**), tillers per meter square (r = 0.599*) and leaves area index (r = 0.553**). Weed data such as weed cover score (r = -0.577**) and weed dry weight (r = -0.553**) displayed significant but negative correlation while for weed control efficiency (r = 0.544**) it is positive and significant association with grain yield. Panicles per meter square (r = 0.553**) and Panicles weight (r = 0.340**) recorded positive and significant relationship with grain yield. Among the growth variables, plant height, dry matter weight and tillers per meter square were all positively correlated among themselves (P < 0.001). Yield components also recorded significant and positive associations with each other and also with growth attributes with the exception of panicles number per meter square. Weed data like weed cover score and weed dry weight recorded significant but negative correlation with both growth and yield characters but positively associated with each

other with exception of weed control efficiency that was positively correlated with growth and yield attributes but negative with weed cover score and dry weight.

Table 31: Correlation of Grain Yield to Growth, Weed and Yield Components as Affected by Weed Control Methods at BUK during 2016 Raining Seasons

| ' | pdyld | pthgt | dmp | tlm | lai | cvs | wcs | wdw | wce | onm | pnwt |
|-------|-----------|-----------|-----------|----------|-----------|---------|-----------|-----------|----------|----------|--------|
| pdyld | 1.0000 | | | | | | | | | | |
| pthgt | 0.5113** | 1.0000 | | | | | | | | | |
| dmp | 0.4401** | 0.5337** | 1.0000 | | | | | | | | |
| tlm | 0.2477* | 0.2746* | 0.2451* | 1.0000 | | | | | | | |
| lai | 0.3610** | 0.3330** | 0.2255* | 0.6562** | 1.0000 | | | | | | |
| CVS | 0.0072 | 0.1962 | 0.0761 | -0.0575 | -0.0502 | 1.0000 | | | | | |
| WCS | -0.5779** | -0.3280** | -0.3172** | -0.2701* | -0.3212** | 0.0159 | 1.0000 | | | | |
| wdw | -0.5539** | -0.4424** | -0.3911** | -0.3117* | -0.3241** | -0.0647 | 0.6501** | 1.0000 | | | |
| wce | 0.5448** | 0.4244** | 0.3501** | 0.1419 | 0.1751 | 0.1684 | -0.6406** | -0.8993** | 1.0000 | | |
| pnm | 0.6210** | 0.1281 | 0.0071 | 0.0785 | 0.1573 | -0.0948 | -0.1244 | -0.0713 | 0.1802 | 1.0000 | |
| pnwt | 0.6902** | 0.5045** | 0.4466** | 0.2332* | 0.3454** | -0.1355 | -0.4932** | -0.5093** | 0.4868** | 0.3695** | 1.0000 |

pdyld – paddy yield, pthgt – plant height, dmp – dry matter per plant tlm – tillers per m^2 , lai – leaves area index, cvs – crop vigor score, wcs – weed cover score, wdw – weed dry weight, wce – weed control efficiency, pnm – panicles per m^2 , pnwt – panicles weight ($r \le 0.005$) *, **=significant at 5% and 1%, respectively

Table 32: Correlation of Grain Yield to Growth, Weed and Yield Components as Affected by Weed Control Methods at DBT during 2016 Raining Seasons

| | pdyld | pthgt | dmp | tlm | lai | cvs | WCS | wdw | wce | pnm | pnwt |
|-------|-----------|----------|----------|-----------|----------|----------|-----------|-----------|---------|--------|--------|
| pdyld | 1.0000 | | | | | | | | | | |
| pthgt | 0.5396** | 1.0000 | | | | | | | | | |
| dmplt | 0.6237** | 0.4868** | 1.0000 | | | | | | | | |
| tlm | 0.5992** | 0.2845* | 0.2616* | 1.0000 | | | | | | | |
| lai | 0.5536** | 0.4844** | 0.4604** | 0.5780** | 1.0000 | | | | | | |
| cvs | 0.1820 | 0.3914** | 0.4166** | 0.1068 | 0.2962* | 1.0000 | | | | | |
| WCS | -0.3443** | -0.2648* | -0.2083* | -0.3667** | -0.2858* | -0.0086 | 1.0000 | | | | |
| wdw | -0.2484* | -0.2715* | -0.2017* | -0.3169** | -0.1840 | -0.0586 | 0.5498** | 1.0000 | | | |
| wce | 0.1945 | 0.2968* | 0.2542* | 0.2226* | 0.1422 | 0.1195 | -0.5419** | -0.9550** | 1.0000 | | |
| pnm | 0.5532** | 0.1969 | 0.0946 | 0.6539** | 0.4420** | -0.0594 | -0.4368** | -0.2686* | 0.1904 | 1.0000 | |
| pnwt | 0.3402** | 0.5048** | 0.4973** | 0.2135* | 0.4115** | 0.3288** | -0.2981* | -0.2370* | 0.26948 | 0.1590 | 1.0000 |

pdyld -paddy yield, pthgt - plant height, dmp - dry matter per plant tlm - tillers per m^2 , lai - leaves area index, cvs - crop vigor score, wcs - weed cover score, wdw - weed dry weight, wce - weed control efficiency, pnm - panicles per m^2 , pnwt - panicles weight ($r \le 0.005$) *, **=significant at 5% and 1%, respectively

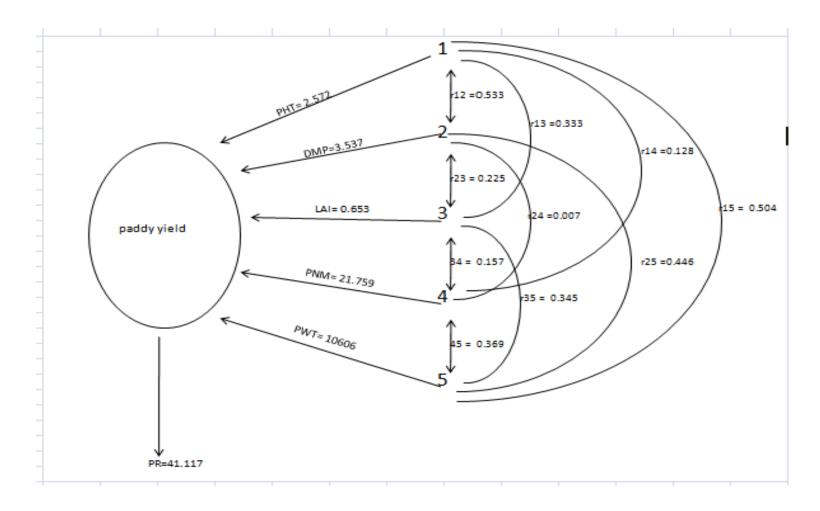


Figure 7: Path Diagram Showing Individual contributions (%) and Interrelations to Paddy Yield at BUK in 2016 raining season

* Single arrowed line represent path coefficient, double line arrowed represent correlation coefficient

PHT = plant height DMP = dry matter weight LAI = leaves area index PNM = panicles number per m² PWT = panicles weight

Analysis of individual and combined contribution of some growth and yield characters by path coefficeint on paddy yield of DBT in 2016 raining season is presented in Table 33 and 34. It could be observed that the highest individual contribution to paddy yield came from the panicles number per meter square and dry matter per plant with 20.526 and 24.817, respectively. Combined contribution of plant height via leaf area index is 3.248% and and for plant height via panicles number was 2.717%. However, when the individual contributions of dry matter weight and panicles weight were partitioned it indicated negligible percentage contribution of 0.098% and 0.004%, respectively. Similarly the highest direct contribution among the parameters observed came from panicles number per meter square 15.660% so also its combined contributions 4.569%, and as such the total percentage contribution of panicles weight was 20.229 percent. The total residual effect was 39.68%.

Result of correlation analysis for BUK in 2017 raining season is presented in Table 35. It indicated significant and positive correlation between grain yield and some growth parameters like plant height ($r = 0.692^{**}$), dry matter per plant ($r = 0.451^{**}$), tillers per meter square ($r = 0.247^{**}$) and leaves area index ($r = 0.351^{***}$). Grain yield also recorded positive non significantly correlated with crop vigor score. Weed data such as weed cover score ($r = -0.250^{**}$) and weed dry weight ($r = -0.492^{***}$) displayed significant but negative correlation while for weed control efficiency ($r = 0.469^{***}$) it is positive and significant with grain yield. Panicles per meter square ($r = 0.300^{**}$) and Panicles weight ($r = 0.605^{***}$) recorded positive and significant relationship with grain yield. Growth variables such as plant height, dry matter weight and tillers per meter square were all positevly correlated among themselves (P < 0.001). Yield components also displayed

significant and positive associations with each other as well as the growth attributes with the exception of panicles number per meter square. Weed data like weed cover score and weed dry weight recorded significant but negative correlation with both growth and yield characters but positively associated with each other with exception of weed control efficiency that was positively correlated with growth and yield attributes but negative with weed cover score and dry weight.

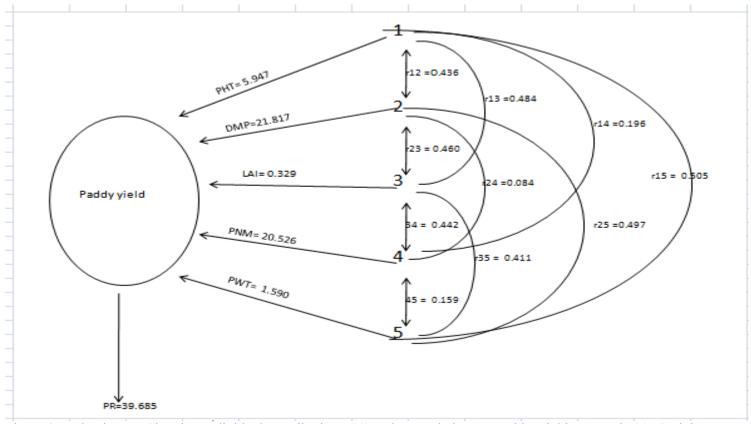


Figure 8: Path Diagram Showing Individual contributions (%) and Interrelations to Paddy Yield at DBT in 2016 raining season

PHT = plant height DMP = dry matter weight LAI = leaves area index PNM = panicles number per m² PWT = panicles weight

Analysis of individual and combined contribution of some growth and yield characters by path coefficeint on paddy yield of BUK in 2017 raining season is presented in Table 33 and 34. It could be observed that the highest individual contribution to paddy yield came from plant height and panicles weight with 26.852% and 17.192%, respectively. Combined contribution of panicles weight via dry matter weight was 3.805% and and for panicles weight via laef area index was 1.385%. However, when the individual contributions of plant height and leaf area index were partitioned they indicated negligible percentage contribution of 0.095% and 0.830%, respectively. Similarly the highest direct contribution among the parameters observed came from panicles weight 23.60% so also its combined contributions was 5.665%, and as such the total percentage contribution of panicles weight was 29.27 percent. The total residual effect was 44.42%.

Result of correlation analysis for DBT in 2017 raining saeson is presented in Table 36. It indicated significant and positive correlation between grain yield and some growth parameters like plant height (r = 0.633**), dry matter per plant (r = 0.500**), tillers per meter square (r = 0.534**) and leaves area index (r = 0.683**). Grain yield also was positively not significantly correlated with crop vigor score. Weed dry weight (r = 0.453**) exhibited significant but negative correlation with yield while for weed control efficiency (r = 0.403**) it is positive and significant with grain yield. Panicles per meter square (r = 0.629**) and Panicles weight (r = 0.453**) recorded positive and significant relationship with grain yield. Growth variables like plant height, dry matter weight and tillers per meter square were all positevly correlated among themselves (P < 0.001). Yield components also displayed significant and positive associations with each other, so also

with growth attributes with the exception of panicles number per meter square. Weed data like weed cover score and weed dry weight recorded significant but negative correlation with both growth and yield characters, but positively associated with each other, except with weed control efficiency that was positively correlated with growth and yield attributes, but negative with weed cover score and dry weight.

Table 33: Path Coefficient Analysis of BUK and DBT during 2016 and 2017 Raining Seasons

| Individual contribution to paddy yield | Percentage contribution (%) | | | | |
|----------------------------------------|-----------------------------|----------|----------|-----------|--|
| | 2016 | | 201 | <u>17</u> | |
| | BUK | DBT | BUK | DBT | |
| Individual contribution | BUK 2016 | DBT 2016 | BUK 2017 | DBT2017 | |
| PHT | 2.5720 | 5.947844 | 26.85248 | 21.71532 | |
| DMP | 3.5373 | 24.81782 | 1.001297 | 1.976968 | |
| LAI | 0.6350 | 0.329346 | 0.10191 | 22.17731 | |
| PNM | 21.7597 | 20.52633 | 0.093087 | 12.65428 | |
| PWT | 10.6060 | 1.590947 | 17.19275 | 0.083327 | |
| Combine contribution | | | | | |
| PHT + DMP | 1.6077 | 5.904701 | 2.136343 | -4.36372 | |
| PHT + LAI | 0.4256 | 0.67741 | 0.488002 | 7.571059 | |
| PHT + PNM | 0.9576 | 2.165666 | -0.34308 | 5.437206 | |
| PHT + PWT | 2.6323 | -1.55038 | 6.725264 | -0.86225 | |
| DMP + LAI | 0.4991 | 1.383737 | 0.094235 | -2.28441 | |
| DMP+ PNM | 1.1230 | 4.423781 | -0.06625 | -1.64056 | |
| DMP+ PWT | 3.0871 | -3.16694 | 1.298669 | 0.260166 | |
| LAI + PNM | 0.4758 | 0.50961 | -0.02114 | 5.494739 | |
| LAI + PWT | 1.3079 | -0.36483 | 0.414309 | -0.87138 | |
| PNM+ PWT | 7.6566 | -2.88014 | -0.39597 | -0.65822 | |
| RESIDUAL | 41.1175 | 39.68509 | 44.42808 | 33.31016 | |
| TOTAL | 100 | 100 | 100 | 100 | |

 $PHT-Plant\ height,\ DMP-dry\ matter\ per\ plant,\ LAI-leavevs\ area\ index,\ PNM$ - panicles per meter square, $PWT-panicles\ weight$

Table 34: Direct and Indirect Contributions of Growth and Yield Components to Paddy Yield at BUK and DBT in 2016 and 2017 Raining Seasons

| | PHT | DMP | LAI | PNM | PWT | total corr |
|-----------------|----------|----------|----------|----------|----------|------------|
| BUK 2016 | | | | | | |
| PHT | 0.160373 | 0.100246 | 0.026535 | 0.059709 | 0.164137 | 0.511 |
| DMP | 0.085479 | 0.188078 | 0.017929 | 0.003265 | 0.145248 | 0.44 |
| LAI | 0.053404 | 0.042318 | 0.079686 | 0.073236 | 0.112356 | 0.361 |
| PNM | 0.020528 | 0.001317 | 0.012511 | 0.466473 | 0.120172 | 0.621 |
| PWT | 0.080828 | 0.083883 | 0.027492 | 0.172129 | 0.325669 | 0.69 |
| DBT 2016 | | | | | | |
| PHT | 0.243882 | 0.242113 | 0.027776 | 0.0888 | -0.06357 | 0.539 |
| DMP | 0.118527 | 0.498175 | 0.026399 | 0.042588 | -0.06269 | 0.623 |
| LAI | 0.118039 | 0.22916 | 0.057389 | 0.200253 | -0.05184 | 0.553 |
| PNM | 0.047801 | 0.046828 | 0.025366 | 0.45306 | -0.02006 | 0.553 |
| PWT | 0.122917 | 0.247593 | 0.023587 | 0.072037 | -0.12613 | 0.34 |
| BUK 2017 | | | | | | |
| PHT | 0.518194 | 0.041227 | 0.009417 | -0.00662 | 0.129783 | 0.692 |
| DMP | 0.213496 | 0.100065 | 0.011716 | -0.00613 | 0.131856 | 0.451 |
| LAI | 0.152867 | 0.036724 | 0.031923 | -0.0061 | 0.135588 | 0.351 |
| PNM | 0.112448 | 0.020113 | 0.006385 | -0.03051 | 0.191564 | 0.3 |
| PWT | 0.162195 | 0.031821 | 0.010439 | -0.0141 | 0.414641 | 0.605 |
| DBT 2017 | | | | | | |
| PHT | 0.465997 | -0.09364 | 0.16247 | 0.116679 | -0.0185 | 0.633 |
| DMP | 0.310354 | -0.1406 | 0.23358 | 0.10992 | -0.01325 | 0.5 |
| LAI | 0.160769 | -0.06974 | 0.470928 | 0.131264 | -0.01322 | 0.68 |
| PNM | 0.152847 | -0.04345 | 0.173772 | 0.355729 | -0.0099 | 0.629 |
| PWT | 0.298704 | -0.06454 | 0.215685 | 0.122015 | -0.02887 | 0.543 |

Bolded = direct contribution, Total corr – total correlated, PHT – Plant height, DMP – dry matter weight, LAI – leaves area index, PNM – panicles number per meter square, PWT – panicles weight

Table 35: Correlation of Grain Yield to Growth, Weed and Yield Components as Affected by Weed Control Methods at BUK during 2017 Raining Seasons

| | pdyld | pthgt | dmplt | tlm | lai | cvs | WCS | wdw | wce | pnm | pnwt |
|-------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|--------|
| odyld | 1.0000 | | | | | | | | | | |
| thgt | 0.6924** | 1.0000 | | | | | | | | | |
| lmplt | 0.4510 | 0.4129** | 1.0000 | | | | | | | | |
| :lm | 0.2471* | 0.4668** | 0.2732* | 1.0000 | | | | | | | |
| ai | 0.3510** | 0.2953* | 0.3679** | 0.7820* | 1.0000 | | | | | | |
| cvs | 0.1961 | 0.4464** | 0.3953** | 0.2118* | 0.2416* | 1.0000 | | | | | |
| ics | -0.2506* | -0.3987** | -0.3866*8 | -0.2737 | -0.2574* | -0.7154** | 1.0000 | | | | |
| vdw | -0.4925** | -0.3981** | -0.4723** | -0.4099** | -0.3173** | -0.4425** | 0.4773** | 1.0000 | | | |
| vce | 0.4692** | 0.3336** | 0.4265*8 | 0.2626* | 0.1809 | 0.4441** | -0.4861** | -0.8970** | 1.0000 | | |
| onm | 0.3005** | 0.2175* | 0.2014* | 0.1373 | 0.2002* | 0.3071** | -0.3926** | -0.2851* | 0.3753** | 1.0000 | |
| onwt | 0.6050** | 0.3130** | 0.3188** | 0.1778 | 0.3279** | 0.2518 | -0.2575* | -0.3840** | 0.3681** | 0.4628** | 1.0000 |

pdyld -paddy yield, pthgt - plant height, dmp - dry matter per plant tlm - tillers per m^2 , lai - leaves area index, cvs - crop vigor score, wcs - weed cover score, wdw - weed dry weight, wce - weed control efficiency, pnm - panicles per m^2 , pnwt - panicles weight ($\mathbf{r} \leq 0.005$). *,**=significant at 5% and 1%, respectively

Table 36: Correlation of Grain Yield to Growth, Weed and Yield Components as Affected by Weed Control Methods at DBT during 2017 Raining Seasons

| | pdyld | pthgt | dmplt | tlm | lai | cvs | WCS | wdw | wce | pnm | pnwt |
|-------|-----------|-----------|-----------|----------|----------|----------|-----------|-----------|----------|----------|--------|
| pdyld | 1.0000 | | | | | | | | | | |
| pthgt | 0.6331** | 1.0000 | | | | | | | | | |
| dmplt | 0.5004** | 0.6664** | 1.0000 | | | | | | | | |
| tlm | 0.5347** | 0.2242* | 0.2096* | 1.0000 | | | | | | | |
| lai | 0.6839** | 0.3454** | 0.4963** | 0.5245** | 1.0000 | | | | | | |
| cvs | 0.1070 | 0.2373* | 0.2164* | 0.1204 | 0.2309* | 1.0000 | | | | | |
| wcs | -0.1795 | -0.2794* | -0.2228* | -0.2494* | -0.2478* | -0.5280* | 1.0000 | | | | |
| wdw | -0.4535** | -0.4692** | -0.4843** | -0.2881* | -0.2799* | -0.2138* | 0.3750** | 1.0000 | | | |
| wce | 0.4033** | 0.4292** | 0.4405** | 0.2238* | 0.2197* | 0.2515* | -0.3468** | -0.9734** | 1.0000 | | |
| pnm | 0.6294** | 0.3280** | 0.3091** | 0.6346** | 0.3690** | 0.0955** | -0.2958* | -0.3616** | 0.3109** | 1.0000 | |
| pnwt | 0.5433** | 0.6415** | 0.4590** | 0.3164** | 0.4587** | 0.1696 | -0.1690 | -0.6009** | 0.5783** | 0.3436** | 1.0000 |

pdyld -paddy yield, pthgt - plant height, dmp - dry matter per plant tlm - tillers per m^2 , lai - leaves area index, cvs - crop vigor score, wcs - weed cover score, wdw - weed dry weight, wce - weed control efficiency, pnm - panicles per m^2 , pnwt - panicles weight ($\mathbf{r} \leq 0.005$). *, **=significant at 5% and 1%, respectively

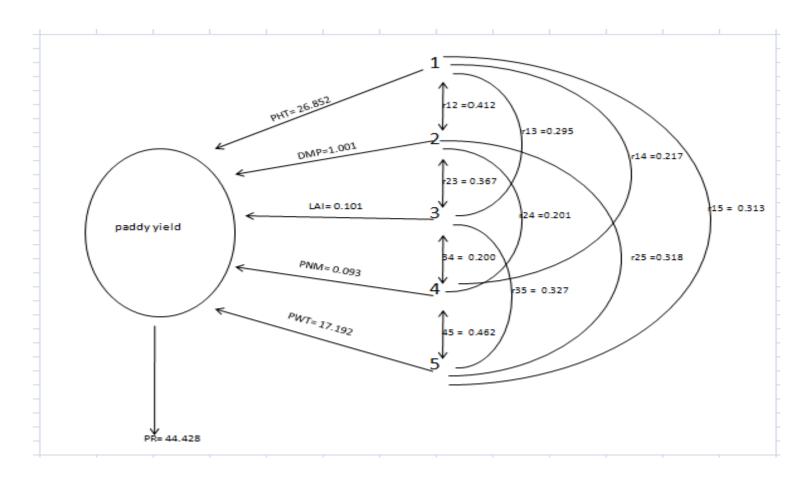


Figure 9: Path Diagram Showing Individual contributions (%) and Interrelations to Paddy Yield at BUK in 2017 raining season

PHT = plant height DMP = dry matter weight LAI = leaves area index PNM = panicles number per m² PWT = panicles weight

Analysis of individual and combined contribution of some growth and yield characters by path coefficeint on paddy yield of DBT in 2017 raining season is presented in Table 33 and 34. It could be observed that the highest individual contribution to paddy yield came from plant height, leaf area index and panicles number per meter square 21.715%, 21.177% and 12.654% respectively. Combined contribution of panicles number per meter square via plant height was 5.408% and and for panicles number via panicles weight was 2.458%. However, when the individual contributions of dry matter and panicles weight were partitioned they indicated negligible percentage contribution of 0.013% and 0.816%, respectively. Similarly the highest direct contribution among the parameters observed came from panicles number 18.022% so also its combined contributions was 9.631%, and as such the total percentage contribution of panicles weight was 27.65 percent. The total residual effect was 33.31%.

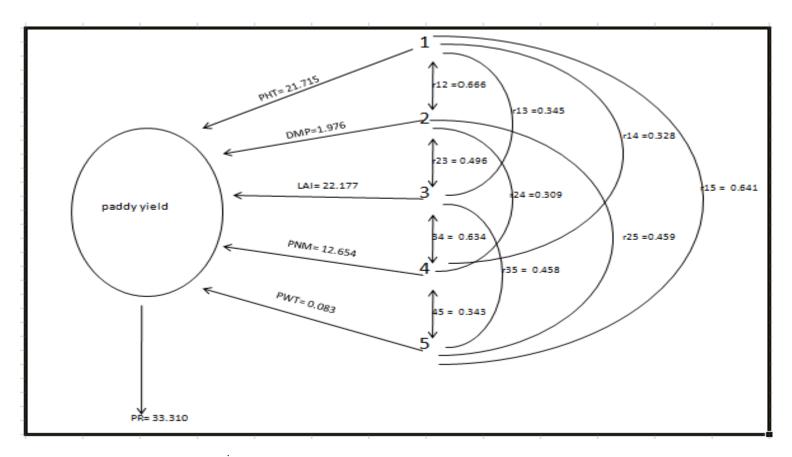


Figure 10: Path Diagram Showing Individual contributions (%) and Interrelations to Paddy Yield at DBT in 2017 raining season

PHT = plant height DMP = dry matter weight LAI = leaves area index PNM = panicles number per m² PWT = panicles weigh

Cost-benefit ratio of weed control methods

Analysis of cost-benefit ratio as affected by different weed control methods on growing upland rice for BUK and DBT in 2016 raining seasons is presented in Figure 11. It could be observed that at BUK in 2016 raining season application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ produced the highest cost-benefit ratio of 1.3 Naira for every Naira invested and this was closely followed by application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹, Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 8 WAS and Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS that gave 1.2 Naira cost-benefit ratio for every one Naira invested and the The least and loss figure was recorded by the weed free (HWC at 2, 4, 6 & 8 WAS) with -1 Naira per every Naira invested. it could also be observed that at DBT in 2016 growing season application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ was more profitable with a cost-benefit ratio of 1.5 per Naira invested but was closely followed by the application of Butachlor at 1.0 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹ and Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹, with 1.4 cost-benefit for every Naira investment. The least and loss figure of -0.9 was recorded by Butachlor at 1.0 kg a.i.ha⁻¹ fb SHW at 4 & 8 WAS and the weedy check.

It could be observed that at BUK in 2017 raining season (Figure 12) application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ and Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 2.8 kg a.i.ha⁻¹ produced the highest cost-benefit ratio of 1.2 Naira for every Naira invested and they were closely followed by the application of Butachlor at 1 kg a.i.ha⁻¹ fb Rainbow at 0.030 k g a.i.ha⁻¹, Butachlor at 1.5 kg a.i.ha⁻¹ fb Rainbow at 0.030 kg a.i.ha⁻¹ Butachlor

at 1 kg a.i.ha⁻¹ fb SHW at 4 WAS among others with 1.1 cost-benefit ratio on every Naira invested. The least and loss figure of -1.1 was recorded by the weedy check. It could also be observed that at DBT in 2017 growing season application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ was more profitable with a cost-benefit ratio of 1.5 per Naira invested but was closely by the application of Butachlor at 1.5 kg a.i.ha⁻¹ fb SHW at 4 WAS with 1.4 cost benefit ratio on every Naira invested. The least and loss figure of -1.0 was recorded by the weedy check.

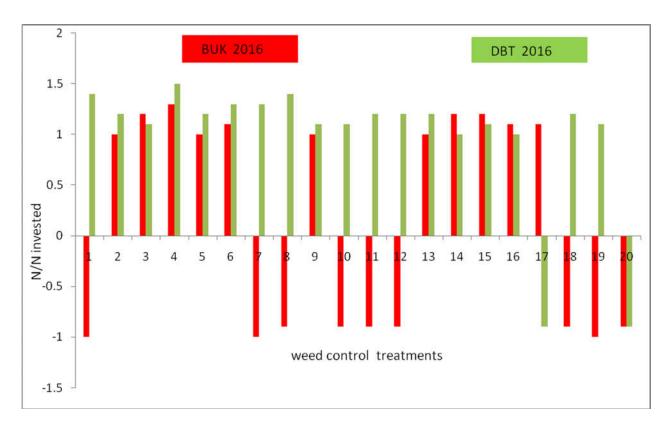


Figure 11: Graphical Presentation of Cost-Benefit Ratio of Growing Upland Rice by Different Weed Control Methods at BUK and DBT during 2016 Raining Season

Key:

| S/N | Treatments | Rate | S/N | Treatments | Rate |
|-----|---------------|---------------------------|-----|-------------------------|---------------------------|
| | | (kga.i.ha ⁻¹) | | | (kga.i.ha ⁻¹) |
| 1 | Buta fb Orizo | 1 fb 2.8 | 11 | Buta fbSolito | 1.5 fb 0.32 |
| 2 | Buta fb Orizo | 1 fb 4.5 | 12 | Buta fbSolito | 1.5 fb 0.48 |
| 3 | Buta fb Orizo | 1.5 fb 2.8 | 13 | Buta fb SHW @ 4 WAS | 1 |
| 4 | Buta fb Orizo | 1.5 fb 4.5 | 14 | Buta fb SHW @ 8 WAS | 1 |
| 5 | Buta fb Rbow | 1 fb 0.025 | 15 | Buta fb SHW @ 4 WAS | 1.5 |
| 6 | Buta fb Rbow | 1 fb 0.030 | 16 | Buta fb SHW @ 8 WAS | 1.5 |
| 7 | Buta fb Rbow | 1.5 fb 0.025 | 17 | Buta fb SHW @ 4 & 8 WAS | 1 |
| 8 | Buta fb Rbow | 1.5 fb 0.030 | 18 | Buta fb SHW @ 4 & 8 WAS | 1.5 |
| 9 | Buta fbSolito | 1 fb 0.32 | 19 | HWC @2, 4, 6 & 8 WAS | _ |
| 10 | Buta fbSolito | 1 fb 0.48 | 20 | Weedy check | _ |

N/N invested = Naira per Naira invested

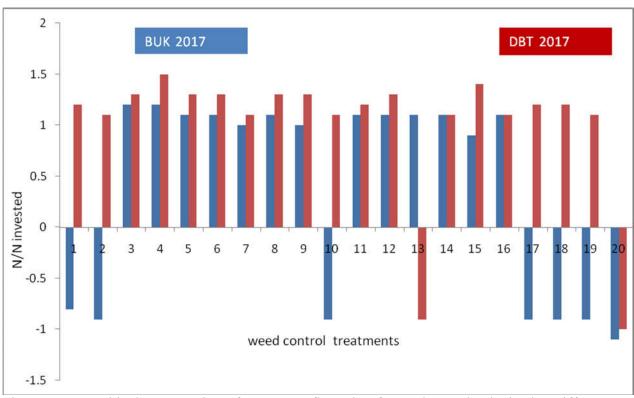


Figure 12: Graphical Presentation of Cost-Benefit Ratio of Growing Upland Rice by Different Weed Control Methods at BUK and DBT during 2017 Raining Season

4.2 DISCUSSION

4.2.1 Weather Data of the Experimental Sites

Recorded data on the rainfall and temperature of both locations and season had shown relatively low rainfall and uneven distribution, but generally rainfall in 2016 was higher than of 2017 and it might probably be the reason for the difference in yield where higher yield was recorded in 2016 than in 2017. The higher yield recorded at DBT in 2016 was probably due to the higher rainfall recorded and well distributed there compared to that of BUK which was suffered dry spelt toward the end of the rainy season. This was in agreement with the findings of Zinolabedin (2008) who reported that, water stress may contribute to yield decrease in rice. It was reported by Robert and John (2012) that, more favourable weather conditions can enhance yield in rice. Prevailing temperature during crop maturity phase also affect grain filling and ripening as well as the activities of soil and air borne diseases organism which may affect the size and quality of the harvested grains.

4.2.2 Soil Physical and Chemical Properties

Soil physical and chemical properties of the two experimental locations in both seasons had shown some similarities especially in the soil pH, organic carbon and total N but they differed in the textural class where the soil for BUK was sandy loam but for DBT it was loamy sand. This could be attributed to the previous cultural practices where cereals crop were solely grown under continuous application of inorganic fertilizers, high rainfall, erosion and weathering at the expenses of the organic nutrition with less effort of alternating with legumes and some deep rooted crops. The high available P at the experimental sites might be connected to availability of P in the dry land soil, its

immobile nature and excessive P fertilizer application more especially at later period of crop growth by most farmers and as such crop cannot make efficient utilization of it.

4.2.3 Weed Interference

Weed Species Composition of upland rice

In weed survey conducted, Rottboellia cochinchinensis, Panicum maximum, Imperata cylindrica, Cynodon dactylon and Cyperus rotundus were found to be among the major weeds of both locations and seasons. This could probably be due to the higher number of seeds produced by grasses which lead to large seed bank in the soil for several years. Weeds such as Rottboellia cochinchinensis and Digitaria horizontalis are very persistent and resist herbicides control due to their hairy and waxy leaf surface combined with their mimicry appearance where by they could escape manual weeding by inexperianced farmers and are of high density at BUK. Earliear Das (2011) stated that weeds ensure their perpetuation through early flowering, maturity and seed shedding. Webster (2000) reported that, annual grasses which include Rottboellia cochinchinensis, Cynodon dactylon, Ipomoea spp and Cyperus spp were the major weed problems of cereal crops in the tropics. The reason behind that might be due to the favorable weed germination and growth medium prevelant at the experimental site as result of favourable moisture, temperature and sunshine at the beginning of the raining season. prevalence of grass weeds such as C. dactylon, D. horizontalis and D. milanjiana in the experimental site in both years of study could have resulted to more yield reduction than broad leaf weeds and sedges. This agreed with the finding of Shari (1985), who reported grass weeds as the most troublesome weed of upland rice because they both belong to Poaceae family and also have similar canopy architecture, hence severe interference. The

observed high density of grasses and high species diversity might be due to high tillering ability of grasses and the wide edaphic adaptability of broadleaf weeds (Akobundu, 1997). Weed density had a significant effect on the beginning of the critical period, the greater the weed density, the shorter the time the crop could tolerate the early-season weed competition (Dillehay *et al.*, 2011). Martin *et al.* (2001) reported that the end of the critical period was less affected by the weed density than the beginning of the critical period since the crop became more competitive at the later growth stages. Generally, the critical period for weed control for a given crop species varies greatly and depends on the density of weed infestation, weed species characteristics, crop species characteristics, climatic conditions, and environment (Knott and Halila, 1986).

It could be identified that the weed species composition of the experimental sites had some similarity with each other, whereas weeds such as *Digitaria horizontalis*, *Cyperus rotundus*, *Cynodon dactylon* and *Rottboellia cochinchinensis* were common at the BUK and DBT experimental sites, and are not easily controlled due to their strong root system high seed production and fast growth. This might probably lead to yield reduction as result of intense competition for farm resources. In another report Ekeleme *et al.* (2004) stated that, Broadleaved weeds were easier to control through cultural practices than grasses and sedges that possess adaptive features for vegetative propagation, which facilitate their regeneration in subsequent years without changes in species. The emergence patterns of the competing weed species and size of the weed seed bank are both important factors influencing the timing and length of the CPWC (Martin *et al.*, 2001; Van Acker *et al.*, 1993). The periodicity of weed emergence is a function of both the weed species and its interaction with the micro-environment (Forcella *et al.*,

1997). A larger seed bank may result in greater weed density but has little effect on the time of weed emergence. Weed density appears to be more important in the determination of the beginning of the CPWC, whereas it has a less notable effect on its end (Martin *et al.*, 2001). In addition, results from numerous weed threshold studies indicated that the relationship between density and yield loss is important but not consistent. In fact, most of the times the relative weed emergence time was more important than the actual weed density (Knezevic *et al.*, 2002). Several researchers have indicated that the end of CPWC was not stable but was highly dependent on the density, competitiveness, and emergence periodicity of the weed population (Evans *et al.*, 2003, Norsworthy and oliveira, 2004). The degree of interference between crop and weeds was determined in part by limiting resources like water, nutrients, and light. The yield components and final yield is therefore, the result of the rice ability to capture available resources throughout the growing season.

Effect of weed interference on growth attributes of upland rice

Increased growth in response to weed control is usually explained in terms of improved access of the crops to water, space and nutrients. This access leads to the enhancement of the crops physiological activity leading to an increase in the leaf area, light interception and photosynthetic activity of the crop. The plant height, number of tillers per plant, dry matter per plant and other growth characters of rice were significantly influenced by weed competition period and as such increase in the length of weed interference period can cause decrease of such characters. The highest mean figure in growth were found in season-long weed-free treatments while the season-long weedy treatments resulted in low performance among most of the growth attributes observed.

The result indicated that growth characters like crop growth rate, effective tillers, dry matter weight of rice were adversely affected by increasing the length of weed interference period which might be due to reduced ability of rice to compete for light and nutrition and increasing the disadvantage of the crop in weed competition. Azmi (1990) and Begum *et al*, (2008) pointed that the growth characters of rice decreased when weeds were allowed to compete for longer time. Chauhan and Johnson (2010) noted rice growth was significantly reduced by competition with *Rottboellia cochinchinensis*, and the reduction was increased in higher weed density. Growth attributes such as plant height, leaves area dry matter weight and crop vigor were generally better in the longer weed free periods. This might be as a result of the availability of environmental resources like soil nutrients, soil moisture, solar radiation and space which were fully utilized by rice crop due to absence of noxious weed like *R. cochinchinensis* (Lour.) Clayton and *O. longistminata* (A) Chev. that may have compete with the rice.

Effect of weed interference on yield components of upland rice

The number of panicles per plant, panicles length, panicles weight and 100 grain weight of rice were significantly reduced by the effect of weed competition period. The results revealed that yield components were significantly higher in weed-free treatments than weedy treatments. The result indicated that yield characters of rice were adversely affected by increasing the length of weed interference period which might be due to reduced ability of rice to compete with weed for limited environmental resources. The results were in accordance with the findings of Azmi (1990), who suggested significant decrease in panicles numbers with increasing weed competition period. Similarly, the reductions in the filled grains per panicles have been widely reported by different authors

due to weeding duration and season long weed competition (Ekeleme *et al.*, 2007; Begum *et al.*, 2008). Under carefull observation it revealed that, yield and yield attributes such as panicles weight, numbers tillers per m², 1000-grain weight and paddy yield were generally better in the longer weed free periods, this might be as a result of weed free environment enjoyed by the crop during their active growth period, thereby untilizing all land resources like soil nutrients, soil moisture, solar radiation and space. This implies that absence of weed makes the rice crop to fully utilize all the environmental resources necessary for growth hence higher yield characters.

Effect of weed interference on yield of upland rice

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 which were 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 to 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 (Amadou *et al.*, 2013). 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.

Singh *et al.* (2002) observed that, maintaining weed free condition till maturity gave significantly higher grain yield due to more panicles per meter square, lower density and dry weight of weeds. Weedy environment throughout the crop growth caused yield reduction to the tune of 57 -61 per cent in case of transplanted rice and 64–66 per cent in case of direct seeded rice (Mukherjee *et al.*, 2008). The yield response to treatments is directly related to either the length or the lack of weed competition. 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.

Past studies have determined the critical period of weed control (CPWC) using Duncan multiple range test or LSD (Harris and Ritter, 1987). Nowadays, Regression analysis has been suggested as a more appropriate and useful means of determining the critical period of weed control (Cousens, 1988). Regression analysis could be used to determine critical periods based on a maximum allowable yield loss which was not in the earlier method..

In this study, the Gompertz equation suggested by Cousens (1988) was used to fit the length of the weed control period and yield data. Logistic equation was used to represent the influence of increasing duration of weed interference on yield. 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 experient.

Result from BUK and DBT in 2016 season showed that, the critical time of weed removal, based on 5% yield loss level ended at 10 DAE for both locations while the critical time of weed free period occurred at 66 and 64 DAE, respectively, On the other hand, the critical time of weed removal based on a 10% allowable yield loss level, ended 16 and 16 DAE and the critical time of weed free period occurred at 62 and 61 DAE, respectively, while based on a 15% AYL, the critical time of weed removal ended at 23 and 21 DAE and the critical time of weed free period occurred at 59 and 54 DAE, respectively. The result so obtained could be as a result of prolonged period where the crop was kept weed free which allowed for maximum utilization of farm resources like essential soil nutrients, moisture and solar radiation since there was no serious competition between the cropand the weeds in the case of weed free treatments. With respect to decreasing yield due to longer period of weed infestation, this clearly indicated the competitive effect of weed on crops where they deny them of nutrients for growth and development, provide a hide out for pests and diseases, provide unnecessary shades that reduce the photosynthetic efficiency of planted crops and reduce soil moisture that dissolve nutrients for easy absoption by plant roots. These results are in agreement with earlier findings by Azmi (1990) who stated that, critical period for weed control in upland rice is from 15–30 DAE, though some crop species can be more competitive towards weeds than others (Aldrich, 1987). 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.

In 2017 however, the result at BUK and DBT showed that the critical time of weed removal, based on 5% yield loss level, ended 15 and 8 DAE and the critical time of weed free period occurred at 64 and 68 DAE, respectively. On the other hand, the critical time of weed removal based on a 10% allowable yield loss level, ended 21 and 12 DAE and the critical time of weed free period occurred at 58 and 63 DAE, respectively, while based on a 15% AYL, the critical time of weed removal ended at 26 and 17 DAE and the critical time of weed free period occurred at 53 and 56 DAE, respectively. Similarly in the Philippines, Chauhan and Johnson (2011), estimated CPWC of aerobic rice as between 18 and 52 DAS to obtain 95% of weed-free yield. Thus, 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 (Martin *et al.*, 2001).

The yield was significantly decreased with the increasing span of weed interference but higher yield was recorded in season-long weed-free treatment and vice-versa. The result these findings might be due to differences in rice variety, agro-climatic zone, soil moisture regimes and prevalent weed flora density among the experimental sites. The result also indicated that the rice grain yield was reduced by the weed infestation and the scale of reduction was found according to the duration of weed infestation. It was also reported that grain yield significantly reduced by increasing the weed competition duration by Begum *et al*, (2008). Similarly, Najib (2009) reported that, rice grain yields

were significantly affected by weeding interval. Chauhan and Johnson, (2011) reported as high as 95% yield reduction in rice due to weed competition throughout the rice growing season. These findings might be due to differences in rice variety, agro-climatic zone, soil moisture regimes and prevalent weed flora density among the experimental sites.

Point of intersection on the interference curve

In all the figures, there is points of intersection which is between the time during which weeds may remain in the plots and the period of time during which the plots might be weeded, suggesting that a single weeding at this time can prevent significant yield loss. This point indicates the minimum weed-free period is equivalent to the maximum period of competition. Therefore unallowable yield loss should be avoided if control measures are implemented at this one critical time (Roberts 1976; Martin *et al.*, 2001). The critical date for weeding indicates time that a crop can tolerate weed competition before yield loss exceeds the cost of control as defined by Dawson (1970), and a single weeding at this time (critical date for weeding) can prevent significant yield loss and running at a lost (Martina *et al.*, 2014). But the present study did not include the effect of weeding on this specific date, because we are more interested in specifying the time interval one shall keep his field weed free in order to attain certain percentage of yield relative to the yield of weed free control so as to get optimum yield in as far there is efficient increase over the resources invested.

Cost-benefit analysis of weed interference periods

Using biologically meaningful parameters for modeling yield data increases understanding of the relationship between length and onset of weed competition.

Thresholds based on economic calculations improve the validity and relevance of the

CPWC for farmers. We provide a simple approach to implement these calculations into the methodology used for the determination of the CPWC. At the intersection of the "weed-infested interval" with this minimum threshold, all costs are covered but no profit is yet achieved. Profit starts if weed competition is removed when yield in the weed-infested interval is above the corresponding yield at the point of intersection in all the locations and seasons. To realize full economical and yield potential of rice, information on critical period of weed control is essential. This information may lead to less reliance on the use of residual herbicides and to more reliance on well-timed postemergence herbicides. It could be observed that the highest C:B ratio was produced by WF until harvest at all the locations and saesons, but was at par with WF at 56 DAE and WIF at 14 DAE, this is because such treatment produced higher yield which could take care of the cost of weeding and produced in excess to give higher profit. Dunan et al. (1995) used economically critical periods taking into account costs of weed removal in rice and yield gain due to that control to determine the the profitability of the method employed. Additionally, when hand weeding and hoeing have to be repeated over time to keep the crop weed-free as long as needed, these increasing costs must also be acknowledged.

4.2.4 Weed Control Methods

Weed species composition and phytosociological characteristics

Identification of weeds is the basic step for planning sound weed management program depending upon the weed species. Weeds may be classified by their structure and form such as grass species, sedges, or broadleaf weeds. Weeds typically fall into one of three life cycle classifications: annuals, biennials, or perennials. Some weeds may be

classified into more than one life cycle. Weeds are usually best adapted to survive in a crop with a similar life cycle, germination time, or growth habit. The most effective control methods often are based on the life cycle of a weed. Different weed management options are given, keeping in view their susceptibility when growing in a crop (Walia, 2006). Weed characteristics that allow them to grow and be competitive with desirable plant species include the ability to germinate and grow in many different environments, rapid seedling growth that allows them to be competitive quickly, ease of pollination, the ability to reproduce vegetatively, and the ability to tolerate adverse environmental conditions. In another report by Akobundu (1987) and Zimdhl (2007) they asserted that, most grasses and sedges were adapted to overcrowding and can survive in a densely populated area like in DBT in both growing seasons.

The dominant grass weed species identified were Rottboellia cochinchinenesis, Digitaria horizontalis, Cynodon dactylon and Eleusine indica, the sedges were Cyperus iria, Cyperus rotundus and Fimbristylis miliacea and broad-leaved weed species were Senna occidentalis, Ipomea asarifolia and Amaranthus spinosis. Kikon and Gohain (2016) identified dominant weed species in direct seeded rice as Digitaria setigera, Cynadon dactylon (L.), Eleusine indica (L.) Gaertn., Echinochloa colona (L.), Cyperus rotundus L., Cyperus irria L. and Borreria articularis (L.) under puddled condition of sandy clay loam soil during raining season. In another work Johnson (1997) summarized the weed species as Amaranthus spinosus, Commelina spp, Cyperus spp, Cynodon dactylon and Rottboellia cochinchinensis as the most common in DSR and that are considered to be of economic importance in Africa. Such species are considered major as they are competitive with rice and individually may cause severe yield loss and are

usually abundant. It could also be observed that some of the important grass weed species where found to replicate themselves in both locations and seasons. It was also confirmed by Das (2011) that, weeds are sometime specific to certain crops and environment due to biotic and crop management practices, soil and climatic parameters in the cultivated land.

The weed flora of the experimental site was similar during both years and comprised of Rottboellia cochinchinensis, Digitaria horizontalis, Cynodon dactylon, Cyprus rotundus, Ipomea asarifolia, Eluesine indica, Fimbriyalis ferruginea, Kyalingya squamulata etc. All the weed control treatments significantly reduced the weed population over the weedy check. Maximum reduction in total weed density and total weed dry weight and weed cover score was recorded by the application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ and manual hoe weeding. High weed density and frequency retard crop growth, encourages disease problems, serve as alternate host for deleterious insects and diseases, slow down harvesting operation, increase the cost of production and reduce the market value of crops (Akobundu, 1987). Effect of legume weed like *Ipomea asarifolia* is less on crop growth compared to grasses like *Rottboellia* cochinchinensis, Digitaria horizontalis, Cynodon dactylon etc. Similar result was recorded by Ishaya et al. (2007a) who reported that, greater reduction in weed dry weight due to herbicides application in rice field. It could also be observed that weedy control treatments recorded higher weed cover score and weed dry weight and this also corroborated with the work of Ishaya et al. (2007a) who also registered higher weed dry weight in weedy plots compared to herbicides control treatments and manual hoe weeding.

Propanil is effective against grassy weeds under dry conditions when the weeds are at the two to three-leaf stage (Umapathy and Sivakumar, 2000). Prolonged usage of one particular herbicide like 2,4-D in the past could lead to a shift in the weed flora, where certain weeds especially many grass species developed resistance. The use of herbicide combinations is therefore appropriate in controlling various species of weeds. Azmi (1990) reported that, post-emergence applications of quinclorac + bensulfuron at 10 DAS and Molinate + 2,4-D applied at 14 DAS controlled more weed species than a single application of either quinclorac or molinate.

Mahadi *et al.* (2007) reported more than 80% reduction in the total weed density over control was observed by the herbicides application (Butachlor, Pendimenthalin and Pretilachlor) which indicates their effectiveness against the weeds. The herbicides also reduced the total weeds dry weight over control treatment (weedy check) very effectively (73.7- 86.8%) which represents their weed control efficiency. Highest reduction in total weed density and total dry weight in hand pulling over the weedy check was possible with the involvement of the intense labor and frequency of the weeding i.e. three times during the growing season (Rao *et al.*, 2007).

Effect of weed control strategies on growth characters

Growth parameters like plant height, leaves area dry matter weight and crop vigor number of tillers per plant were generally better in the herbicides treated plots particularly Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹, this might be as a result of effectiveness of herbicides to control weeds without tempering with the plant population and other nutrients status in the soil medium which could help for effective utilization by the crop during their active growth period, thereby all land -

resources like soil nutrients, soil moisture, solar radiation and space were fully utilized due to absence of noxious weed like R. cochinchinensis (Lour.) Clayton C. esculentus (L) and O. longistminata (A) Chev. that may have compete for them. Significant differences were recorded on growth characters like plant height, leaf area, leaf area index dry matter per plant and tillers per meter square at both locations and growing seasons. This could probably be due to the effect of weed suppression by the herbicides applied as they perform differently in their ability to eliminate or retard weeds growth and competition for farm resources. Severe infestation of weeds suppressed plant height, increased tiller mortality and decreased shoot and grain production. Singh et al. (2006) observed that maintaining weed free condition till maturity gave significantly higher grain yield due to more panicles meter square and lower density and dry weight of weeds. The abilty of weed to compete better with crops can affect the growth and utilization of environmental resources. The high weed infestation at BUK was probably be due to high weed seed in the seed bank which germinated and compete strongly with rice crop. Increased plant height in weed control treatments than the weedy check indicated the improvement in crop growth due to relative weed free environment as a result of implemented treatments (Tewary and Singh, 1991). Walia, (2006) also reported that, the greatest loss caused by the weeds resulted from their competition with crop for growth factors like nutrients, soil moisture, light, space, etc. It was also reported that severe weeds infestation suppress the plant height (Bhargavi and Reddy, 1994) increased tiller mortality, decreased shoot and grain production (Srinivasan and Palaniappan, 1994). Chauhan and Johnson (2010) stated that, when direct seeded rice was grown together with either jungle rice or *Ludwigia* spp, shoot competition reduced the growth and yield of rice more than root competition and

rice grain yield was highly correlated with above and below ground biomass of the weeds.

Generally plots that received higher dose of Butachlor (1.5 kg a.i.ha⁻¹) and Orizoplus (2,4-D-propanil at 4.5 kg a.i. ha⁻¹) mixture and those with supplementary hoe weeding (8 WAS) after herbicide application displayed better growth attributes. This maens that these herbicides are not harmful to the crop but phytotoxic to the weeds. Earlier on, similar result was recorded by Mahadi (2004) who stated that, application of higher rate of Propanil and 2, 4-D (1.2+0.8, 1.8+1.2 kg a.i. ha⁻¹) mixture recorded higher leaves area, leaves area index and crop growth rate. It has been observed by Danmaigoro et al. (2016) that, throughout the two seasons application of highest rates of Propanil plus 2,4-D at 1.2+0.8, 1.8+1.2Kg.a.i/ha and two hoe weeding resulted to a higher crop growth rate and increased relative growth rate . This observation could be due to good weed control that allowed the crop to develop more and larger leaves and consequently higher light interception for increased dry matter accumulation per plant per unit area of land. In another report Mitra (2005), observed that, propanil + 2,4-D mixture applied at 1.6+1.5 kg a.i. ha⁻¹ effectively controlled weed in rice which subsequently led to higher dry matter weight, crop vigor score and crop growth rate. Penoxsulam 25.0 g/ha applied at 3 DAT and 20.0-22.5 g/ha applied at 10-12 DAT was at par with the Butachlor, Pretilachlor and weed free check with respect to rice grain yield (Singh et al., 2007). Efficacy of Penoxsulam in controlling weeds and increasing rice grain yield was also reported by Jason et al. (2007) and Mishra et al. (2007). Singh et al. (2007) reported that, comparatively lower doses of Penoxsulam could be used when it was applied at early post-emergence (8-12 DAT).

Effect of weed control treatments on yield and yield components

It could be observed that higher dose of Orizo-plus (propanil-2,4-D mixture) at 4.5 kg a.i. ha⁻¹ recorded higher yield and its components than all other treatments in both locations and growing seasons. The increase in paddy yield with efficient weed control treatments may be attributed to better crop growth and weed supression in the absence of weed-crop competition for any of the growth factor. Grain yield in rice is mainly determined by number of panicles per unit area, panicle and grain weight. In this study application of Orizo-plus (propanil-2,4-D mixture) at 4.5 kg a.i. ha⁻¹ significantly more number of panicles per square meter and also higher panicle weight which had contributed to higher grain yield in this treatment. The improved yield parameters and hence higher grain yield in the case of Orizo-plus (propanil-2,4-D mixture) at 4.5 kg a.i. ha⁻¹ was mainly attributed to weed free environment as a result of effective reduction of growth of all categories of weeds such as sedges, grasses and broad leaf weeds as well as total weeds. The weed free environment thus created helped the rice crop to put forth better growth without any competition for nutrients and in turn resulted in higher grain yields. Ishaya and Dauda (2010) have reported that, application of 2, 4-D + Propanil at 1.44 + 0.8 kg a.i ha-1 and Butachlor + Propanil at 2.4 + 0.8 kg a.i ha-1 resulted in less crop injury, higher total dry weight and grain yield of rice than the other herbicide treatments. Mishra et al. (2007) observed that, weed infestation of 100 to 200 weeds per meter square reduced paddy yield by 51 to 64% compared with weed-free conditions. Rice plots without such competition recorded higher number of productive tillers over control because of the greater space and nutrients captured by rice plants. The canopy closure occurred earlier due to better competitive ability and nutrient efficiency

(Baloch et al., 2005). Mahajan et al. (2009) concluded that, herbicides are the most effective means of securing rice yields against weeds. In another report by Yawale et al. (2015) confirmed that, Application of Butachlor at the rate of 2.25 kg a.i. ha⁻¹ followed by Propanil - 2, 4 - D mixture at the rate of 2.52 and 1.44 kg a.i. ha⁻¹ respectively, produced higher number of tillers per plant, grain bearing panicles and grain yield per hectare. From the foregoing discussion it could be seeing that, Yield and yield attributes such as panicles weight, numbers tillers per m², 1000-grain weight and paddy yield were generally better in the herbicides treated plots particularly Application of Butachlor 1.5 kg a.i.ha⁻¹ fb Orizo plus 4.5 kg a.i.ha⁻¹ this might be as a result of effectiveness of herbicides to control weeds without tempering with the plant population and other nutrients status in the soil medium which could help for effective utilization by the crop during their active growth period, thereby all land resources like soil nutrients, soil moisture, solar radiation and space were fully utilized due to absence of noxious weed like R. cochinchinensis (Lour.) Clayton C. esculentus (L) and O. longistminata (A) Chev. that might have compete for them.

Zhang (2001) reported that, in China, 10 million tons of rice is lost annually due to weed competition, such a quantity of rice is sufficient to feed at least 56 million people for one year. The aggressiveness of weeds when it comes to competition for such growth factors as moisture and nutrients with rice crop might have been the reasons for the low productivity of rice (Ishaya *et al.*, 2007b). Heavy weed infestation in direct seeded rice, upland or lowland, has been reported to cause as high as 44 - 100% yield loss (Akobundu, 1987). Globally, actual yield losses due to pests have been estimated at 40%, of which weeds caused the highest loss (32%) (Rao *et al.*, 2007). Eskandari *et al.* (2011)

also have reported that, application of herbicides increased the performance of rice yield. Singh *et al.* (1994) reported that, combined application of herbicide + two mechanical weedings was more effective in reducing weed growth and maximizing grain yield.

Correlation and path coefficient of growth and yield parameters

Result from correlation analysis conducted had shown positive and significant correlation with grain yield and growth characters like plant height, tillers per m² leaf area index and dry matter weight. The result indicated strong interrelationship of some physiological activities like photosynthesis, nutrient uptake and translocation of assimilates via the leaves which can enhance the yield and its components. The strong association that existed between the growth and yield components suggest that such characters can be used during crop improvement process since they have direct effect on yield. Similar report was also filed by Jayasuldha and Sharma (2010) and Zulgarnain et al. (2012) who all observed the importance of growth characters in enhancing yield. Total tillers were positively correlated with productive tillers and panicle length and number of grains per panicle. Gupta et al. (2007), had recorded positive and significant correlation of panicle weight with grain yield. Grain yield per plant showed positive significant association with plant height, number of tillers per plant, number of productive tillers per plant and number of filled grains per panicle. This indicated that all these characters were important for yield improvement. Similar kind of association was revealed by Mohanty et al. (2012), Reddy et al. (2013) and Patel et al. (2014), hence, these characters could be considered as criteria for selection for higher yield as these were mutually and directly associated with grain yield.

Knowledge of interrelationship between growth and yield characters is useful in crop improvement programme more especially quantitative attributes like paddy yield in rice. The path coefficient analysis suggested by Dewey and Lu (1950) specified the effective measures of direct and indirect causes of association and also depict the relative importance of each factor involved in contribution to yield. Direct effects tell how a one unit change in X will affect Y, holding all other variables constant. However, it may be possible that other variables are not likely to remain constant if X changes, e.g. a change in X can produce a change in Z which in turn produces a change in Y. Putting another way, both the direct and indirect effects of X on Y must be considered if we want to know what effect a change in X will have on Y, i.e. we want to know the total effects (direct + indirect) (Mugemangango and Vinod, 2011). It could be noted in this resaerch that Positive direct effect was observed among different growth, yield and yield componenets like plant height, dry matter weight, tillers and panicles per meter square etc. This may be as a result of contribution of one character over another and that could translate to better growth, tillering and more number of panicles per unit area. In a report by Silitonga (1989) he observed significant positive correlation between number of filled grain and grain yield. In another work by Mugemangango and Vinod (2011) they found panicle number and panicle weight to have positive direct effects on the grain yield. The high residual effect observed across location and season indicated that there are other factors affecting rice productivity that were not considered particularly soil fertility status and lack of enough moisture at critical moisture requirement stages of growth due to non uniform rainfall distribution and the prevalence of stubborn and herbicide resistant weeds like *Rottboellia cochinchinensis* at the site of the experiments.

Economic analysis of different weed control methods

Total variable cost of production, total revenue and other economic analysis of different weed control methods for growing upland rice per hectare had shown higher gross margin and cost-benefit ratio by the use of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹. This is because chemical weed control is cheaper than other ways of weed control and it has good weed control ability which resulted into high yielding which lead to higher return with minimum labor cost. Application of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ recorded highest net profit and gross margin per Naira invested during both 2016 and 2017 raining seasons. Jabran et al. (2012) reported higher productivity and economic returns with penoxsulam in rice production. The cost effectiveness of post emergence herbicide for weed management in aerobic rice is in line with the report of Mahajan et al. (2009) who confirmed the use of herbicide to be an efficient and cost-effective method for weed control in dry seeded rice. Manual weeding can only be adopted where cheap labor is available. Mandal et al. (2011) reported that, both the gross return and net return were maximum under herbicides treatment combination. The weed control cost is maximum for hand weeding (two hand weeding at 30 and 45 DAT) and the lowest for chemical weed management (Hasanuzzaman et al., 2007).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

Recognizing the optimum time for implementing weed management and development of new strategies could help to manage weed in rice. Two experiments were conducted in 2016 and 2017 raining seasons concurrently at two locations (Bayero University Kano and Audu Bako College of Agriculture, Dambatta Teaching and Research Farms) both in Kano State within the Sudan savanna agro-ecological zone of Nigeria. The aim of the study was to determine the critical period of weed interference and the effectiveness of some weed management strategies in upland rice production. The treatments for the weed interference experiment comprised two sets of weed removal process, the first was weed free periods, where plots were maintained weed free at 14, 28, 42, 56 days after emergence (DAE) and until harvest, while the second set namely weed infested periods, the weeds were allowed to compete with rice crop right from their emergence at 14, 28, 42, 56 DAE and until harvest. The second experiment consisted of twenty weed control strategies by the use of Butachlor at two levels i.e 1.0 and 1.5 kg a.i. ha⁻¹ (pre-emergence), Orizo-plus (2,4-D + Propanil) at two levels i.e. 2.8 and 4.5 kg a.i. ha⁻¹, Rainbow OD (Penoxsulam) at two levels i.e 0.025 and 0.030 kg a.i. ha⁻¹ and Solito 320 EC (Pretilachlor + Pyribenzoxim) also at two levels i.e 0.320 and 0.480 kg a.i. ha⁻¹ (post-emergence). Supplementary hoe weeding was followed after herbicides application in some cases, weed free and weedy checks were also included to serve as control.

The result for weed interference experiment indicated growth characters, yield components and paddy yield increased with the increasing length of weed-free period

and conversely decreased with delay in weed removal; in both seasons and locations. The result for weed control methods experiment on the other hand indicated the use of higher dose of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ resulted in significantly higher number of tillers and panicles per meter square, panicles weight and paddy yield. Weed cover score and weed dry weight were drastically reduced by these herbicides, though the result was at par with weed free control (HWC at 2, 4, 6 & 8 WAS), but it was not economically rewarding.

5.2 CONCLUSION

Productivity of direct-seeded upland rice is believed to largely be dependent on timely and effective weed control. This research work was able to discover the critical period of weed interference and the most effective weed management strategy in direct seeded upland rice. This knowledge provides a highlight on the correct time of using different herbicides combination at optimum rate to be applied during both pre and postemergence growth phase and maintaining cost effectiveness. The results of this study indicated that the maximum rice yield losses due to the highest weed interference were 55%, as compared to the weed free checks. Maintaining weed free conditions for a specific interval of time will help to attain certain level of allowable yield losses, for instance under similar experimental conditions upland rice field shall be kept weed-free during 10-66 and 10-64 DAE at BUK and DBT, respectively, in 2016 to achieve 95% of weed-free yield, while in 2017 it shall be during 15 - 64 and 08 - 68 DAE at BUK and DBT, respectively, to achieve 95% of the weed-free yield. Use of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ proved most effective and economical herbicides combination for better weed control and could replace the taditional manual weeding.

5.3 RECOMMENDATION

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. Based on the result of weed interference experiment it is recommended that, upland rice farmers shall keep their rice field weed free during 10-66 DAE to achieve 95% of weed free yield in the study area. On the weed control strategies, it is recommended that, pre and post emergence herbicides application in form of Butachlor at 1.5 kg a.i.ha⁻¹ fb Orizo plus at 4.5 kg a.i.ha⁻¹ or the use of pre-emergence Butachlor application at 1.5 kg a.i.ha⁻¹ fb supplementary hoe weeding at 4 & 8 WAS, particularly in areas where manual labour is readily available and relatively cheaper, could be used to achieve effective weed control and higher net profit.

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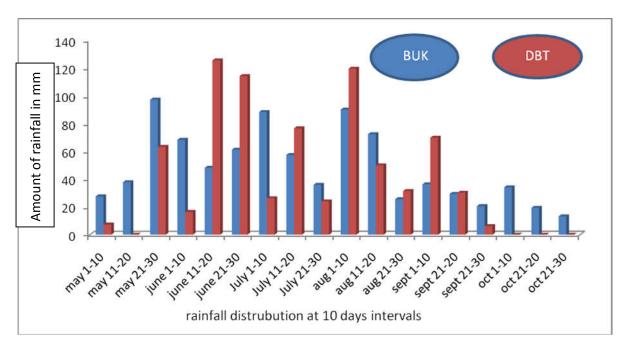
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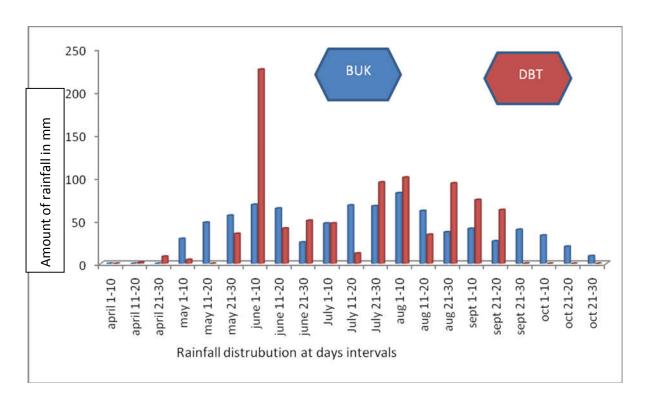
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APPENDICES



Appendix 1: Rainfall distribution for BUK and DBT during 2016 raining season



Appendix II: Rainfall distribution for BUK and DBT during 2017 raining season

Appendix III: Rainfall and Temperature Data for BUK and DBT during 2016 and 2017 Raining Seasons

| | 2016 | | | | 2017 | | | |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Month | | BUK | DBT | | BUK | | | DBT |
| | Tmin (°C) | Tmax (°C) |
| April | - | - | - | - | - | - | 27.0 | 41.1 |
| May | 26.6 | 39.1 | 27.0 | 40.8 | 25.6 | 39.4 | 26.0 | 38.0 |
| une | 24.1 | 35.3 | 23.5 | 37.1 | 23.1 | 36.3 | 23.7 | 34.6 |
| July | 24.1 | 32.6 | 23.7 | 33.6 | 24.1 | 31.6 | 23.2 | 32.9 |
| August | 22.6 | 31.8 | 22.7 | 34.7 | 23.6 | 36.8 | 23.1 | 32.4 |
| September | 22.8 | 33.8 | 22.2 | 35.3 | 23.8 | 33.4 | 22.7 | 33.5 |
| October | 22.0 | 37.0 | 19.8 | 37.7 | 22.0 | 36.9 | 20.1 | 36.6 |
| Total | - | - | - | - | - | - | - | - |

Source: CDA-BUK Weather station records for Bayero University Kano (BUK) and Audu Bako college of Agriculture Weather station record for Dambatta (DBT)