Correlation Analysis of Rice Yield and Weed Parameters as Affected by Post Emergence Herbicides and Seedling Age in Jega Sudan Savanna Zone of Nigeria

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ABSTRACT

The trial was conducted in the Fadama area of Teaching and Research Farm of **Abdullahi Fodio** University of Science and Technology Aliero located at Jega Sudan Savanna zone of Nigeria. The study was instituted to investigate the performance of rice (*Oryza sativa* L.) under the influence of three selected post emergence herbicides and seedling age. The climate of the area is semi-arid with average rainfall of 550-650mm per annum. Temperature averages between 14 – 30 ^{0}C during dry season and 27-41^{0}C during the rainy season. Treatments consisted of three ages of seedling (10, 17 and 24 days old) fourteen weed control methods namely: Bracer at 0.025, Bracer at 0.027, Bracer at 0.030, and Bracer at 0.032kg a.i.ha^{-1}), Bracerplus at 0.021, Bracerplus at 0.023, Bracerplus at 0.025, and Bracerplus at 0.027kg a.i.ha^{-1}, Nomineegold at 0.020, Nomineegold at 0.030, Nomineegold at 0.040 and Nomineegold at 0.050 kg a.i.ha^{-1}, hoe weeding at 4 and 8 weeks after transplanting, and weedy check. The treatments were laid out in a split plot arrangement with three replications. Weed control treatments were allocated to the main plots, while age of seedlings were allocated to the subplots. Results of correlation analysis revealed a significant, strong and positive correlation between crop and yield parameters and a significant and negative correlation between either crops and weed parameters or yield and weed parameters. It is recommended that weed growth should not be allowed to outweigh crop and yield production to avoid economic loss.

Keywords: Analysis, Correlation**,** Herbicides, Jega, Weed Parameters, Rice, Seedling Age, Weed, Sudan Savanna Zone

INTRODUCTION

Rice (*Oryza sativa* L.*)* is an annual grass that belongs to the family Poaceae and genus *Oryza*. It is regarded as the first cultivated crop of Asia (Anon. 2009a). The centre of origin of rice is believed to be south-east Asia (*Oryza sativa)* and Africa *(O. glaberrima*). Some of the important rice producing countries are China, Burma, India Indonesia Japan United States of America, Spain, Italy and Brazil, before it was spread to Africa (Desrosiev, 1999). Although the original parental species of rice are native to South-East Asia and certain parts of Africa, centuries of trade and exportation have made it a common place in many cultures world – wide (IRRI, 2008). Rice is grown in more than 100 countries of varying climatic conditions and is particularly productive in tropical region with abundant moisture (Oko *et al.*, 2012).

Rice is a staple for more than 60 % of the worlds' seven billion people and more than 90% of this rice is consumed in Asia {Mohanty, 2013; Chauhan *et al.*(2014)}. During the year 2017 nearly 482 million metric tonnes of paddy were produced worldwide (Anon., 2018a). Although rice protein ranks high in nutritional quality among cereals, protein content is modest. The minerals, vitamins and other constituents of rice except carbohydrate are reduced by milling (Anon. 2012). In Nigeria, rice is important for several reasons including being a major contributor to internal and sub-regional trade (Oko *et al*., 2012). Two types of rice have been mainly cultivated in Nigeria; the African rice (*Oryza glabberrima)* and Asian rice (*Oryza sativa*) (Oko et al., 2012). In recent times, however new rice varieties have also been introduced including the West African Rice Development Association's (WARDA) hybrid rice varieties e.g. New rice for Africa (referred to as NERICA) which are inter specific hybrid between the African and the Asian rice.

According to a recent documented survey by National Agricultural Extensions and Research Liaisons Services (NAERLS) of Ahmadu Bello University Zaria, in conjunction with Agricultural Development Project (ADPS) and the Federal Department of Agricultural Extension; Niger State produced 545,700 metric tons (MT) of rice to top the National production output for the 2017 wet season. The total land area cultivated by the state for the period was 229,080 hectares. All the 36 states of the Federation, including FCT, were assessed in the survey certified by National Technical Committee on Agricultural Statistics, Kogi state followed with an output of 512,610MT cultivated on 235,521 hectares. Benue was in the third position with a production volume of 486,620MT cultivated area was 227,730 hectares. Kano (418,480), Kebbi (411,490), Nasarawa (410,820), Kwara (408,250) and FCT (408,111) were rated 4th, 5th, 6th, 7th and 8th respectively. The ranking also showed that AkwaIbom with a volume of 19,199MT was the least rice producing state in 2017, with a little over 10,000 hectares of land cultivated. Other lesser producers are Delta (44,230mt) in 36th position and Abia (50,312MT) in 35th place. According to the Agricultural performance survey, the estimated cropped area for rice was 3.90 million hectares which represented an increase of about 6.9 percent over the 3.17 million hectares cultivated in 2016. The survey indicated that a total output of 8.02 million MT was produced in 2017 as against the 6.99 million MT recorded in 2016, showing a significant increase in output of about 14.7 percent (Olawole, 2018).

Rice farmers choose varieties adapted to the region's length of growing season, soil, altitude and the depth of water in the field (Oko *et al*., 2012). Farmers in developing countries usually sow rice seeds in small seed beds, then transplant the seedling into flooded field that have been levelled. For this study, Faro 44 was chosen because of its yield potentials and adaptability in the study Area.

Of the biotic and abiotic stresses that pose constraints to rice production, weeds are the most prominent of them across the ecologies in terms of yield reduction, labour demand and cost of control (Akinyemiju and Igori 1986; Pandey, 2009). Islam *et al* (2005) cited that about 20% of production costs incurred by farmers are attributed to weed control during growing season. In sub-Saharan Africa, 2.2 million tonnes of rice yield is lost annually as a result of uncontrolled weeds (Oyebanji and Oluyemisi 2017). About 28-74% of rice yield is lost due to uncontrolled weed growth in transplanted lowland rice, while 48-100% loss in upland ecosystems (Rodenburg and Johnson 2009).

Weeds are real constraints to rice production (Kwesi and De Datta, 1991). Improved weed control can increase rice yields by 15-23% depending on the agro-ecosystem (Rodenburg and Johnson 2009). As an alternative to hand weeding and other methods of controlling weeds among farmers, herbicides offer a practical and economical option for reducing crop losses and production cost (Akinyemiju and Igori, 1986; Akobundu, 1987, Kolo, 2004). The use of herbicides in rice cultivation is gaining widespread acceptance among rice farmers worldwide including Nigeria. The conventional method of weed control in rice, i.e. hand weeding is very laborious, expensive and inefficient. Chemical weed control can be considered as a better alternative (Singh, and Singh 1993). Use of chemicals to control weed has been found to be effective and economical (Singh and Mani, 1981). Brar and Mishra (1989) reported that chemical weeding is easier, saves time and economical as compared to hand weeding alone. Weed control using herbicides offers an advantage to save labour and money. It is regarded as cost effective method of weed control as opined by Ahmed *et al*, (2000). Sharma *et al*, (1999) stated that herbicides gave significant control of weeds when applied one day after transplanting rice. In China and South Korea rice is treated with herbicides by 70% and 90%

respectively. Moody (1982) stated that herbicide use moves the agro-ecosystem to low species diversity with new problem weeds appearing, so that there is need for the use of post emergence herbicides to manage the weeds.

Post emergence herbicides are a major tools used to control weeds in rice. 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 (*Avenafatua* L.) when applied at an early growth stage (Friesen *et al*., 1976). Conversely, trifloxysulfuron was more effective on yellow nut sedge (*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 desired level of control (Singh and Singh, 2004). Therefore, optimum time of herbicide application and range of herbicides may help control these weeds effectively (Gopal *et al*. 2010).

Statement of the Research Problem

Weeds are recognised as major biological constraints that hinder the attainment of optimal rice productivity and quality (Kumar and Ladha, 2011, Rao and Nagamani, 2013). It is estimated that every year, weeds cause yield losses from 15 to 76% in rice crop (Singh *et al.*, 2004, Mondal *et al*., 2005, Rao and Nagamani 2010, Mishra *et al*., 2012, Mandal *et al.*,2013). Direct yield loss has been estimated to range from 16 – 86% depending on type of rice culture, cultivars, weed species and density, duration and time of weed infestation, climatic and environmental conditions (Duary *et al*., 2004, Kolay 2007). It is well established that weeds remove considerable quantities of nutrients from rice crop field. Estimate showed that weeds can deprive the rice crops by 47% N, 42% P, 50% K, 39% Ca and 24% Mg of their nutrient uptake thereby reduce the yield potential of the crop (Balasubramaniyan and Palaniappan 2001). Hence timely and effective weed control is essential for obtaining higher yield of rice (Sathyamoothy *et al*., 2004, Kumar *et al*., 2007). Nutrient removal by weeds has been reported to be about 21 – 42kg N, 10 – 13.5kg P and 17 – 27 kg K ha^{-1} in transplanted rice depending upon the soil, condition of cropping and location of growing rice (Sudhalakshmi *et al.*,2005, Puniya *et al.*,2007b, Gowda *et al.*,2009). In rain-fed lowland rice, a period of 30-60 days after sowing was considered as critical period for crop weed competition to avoid grain yield losses (Moorthy and Saha 2005). Therefore weed control measures must be instituted before this period of time to avert economic yield loss in rice.

Justification of the study

Chemical weed control is a practical and economic alternative to hand weeding. The conventional method of weed control in rice, i.e. hand weeding is very laborious, expensive and inefficient. Chemical weed control can be considered as a better alternative (Singh, and Singh 1993). Use of chemicals to control weeds in rice, has been found to be effective and economical (Singh and Mani, 1981). Brar and Mishra (1989) reported that chemical weeding is easier, saves time and economical as compared to hand weeding alone. Weed control using herbicides offers an advantage to save labour and money. It is regarded as cost effective method of weed control as opined by Ahmed *et al.,* (2000). Sharma *et al*. (1999) stated that herbicides gave significant control of weeds when applied one day after transplanting rice. Application of herbicide appropriately prevents weed infestation from planting to harvesting and promotes higher yields by allowing closer crop spacing and therefore higher plant population (Imoloame, 2017). The use of herbicides in intensive rice cultivation is gaining widespread acceptance among rice farmers in Nigeria. Consequently, there is a dire need to continuously evaluate new selective post emergence herbicides for broad spectrum weed control in rice field, therefore a selective broad spectrum herbicide for control of grasses, sedges and broad leaved weeds in a single spray in rice field is required.

Weed infestation causes reduction in crop yield and grain quality (De Datta, 1979). Akobundu (1989) reported that uncontrolled weeds can cause up to 80-100% yield losses in Nigeria. Weed control is one of the major labour demanding farm operations in rice production; the labour requirement is very costly and may not be available at the

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time of need (Yawale *et al.*, 2019). Although no single weed control method can give effective and satisfactory weed control in all ecologies, however, chemical weed control may provide a better alternative, because it is fast, cheap, easy and more effective, Lagoke, *et al.*(1991).

Aim and Objectives of the Study

The aim of the study was to evaluate three selected post emergence herbicides for weed control in the rice variety, while the specific objective was to determine the effect of herbicides on weed suppression and the correlation of rice growth and yield factors with associated weeds.

MATERIALS AND METHOD

Experimental site

The experiment was conducted in the 2020/2021 and 2021/2022 dry seasons of at the Fadama area of the Teaching and Research Farm of Kebbi State University of Science and Technology Aliero located at Jega on the latitude. 12^0 18.64'N: longitude 04^0 29.85', and altitude 262 m above sea level. The area is characterized by erratic and scanty rainfall lasting about 5 months (from the month of May – September) and long dry periods (October – April). The area's climate is semi-arid with an average rainfall of 550-650 mm per annum. The relative humidity ranges from 21-47% and 51- 79% in the dry and rainy seasons, respectively. Temperature averages between 14 – 30 ^{0}C in the dry season and 27-41^{0}C in the rainy season (Anonymous, 2012).

Soil sampling and analysis

Soil samples was collected from random points within the (lowland) experimental site at Teaching and Research Farm of Kebbi State University of Science and Technology located at Jega. The samples was collected within the depth of 0-30 cm at four locations using a 10 cm diameter soil auger. The samples was bulked, air dried sieved and then subjected to routine laboratory analysis for physico-chemical properties following the standard procedures. (Black,1965).

Treatments and Experimental Design

Treatments consisted of three ages of seedling (10, 17 and 24 days old) fourteen weed control methods namely: Bracer at 0.025, Bracer at 0.027, Bracer at 0.030, and Bracer at 0.032kg a.i.ha^{-1}), Bracerplus at 0.021, Bracerplus at 0.023, Bracerplus at 0.025, and Bracerplus at 0.027kg a.i.ha^{-1}, Nomineegold at 0.020, Nomineegold at 0.030, Nomineegold at 0.040 and Nomineegold at 0.050 kg a.i.ha^{-1}, hoe weeding at 4 and 8 weeks after transplanting, and weedy check. The treatments were laid out in a split plot arrangement with three replications. Weed control treatments were allocated to the main plots, while age of seedlings were allocated to the subplots.

Cultural practice

Field layout and Plot size

The field was cleared ploughed harrowed and levelled to allow for free flow of water. Plots were marked out. The plot size was 2 x 2m =4m^2 separated by 1m space between the plots of the same replicate, while 2m space was provided between blocks. The inter and intrar row spacing was 20x20cm with two seedling per stand, the net plot area (1.80m^2) contained ten (10) middle rows for growth and yield assessment, while the boarder rows were used for destructive sampling. The total plot area was 14 x 22m = 396m^2

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Nursery preparation

Three nursery beds were prepared for Faro 44 with dimensions of 5x2m (10m^2). The beds were fertilized with NPK 20:10:10 at 50gm^{-2}. The rice seeds were sown by drilling at an inter row spacing of 30cm. The beds were adequately irrigated in every two days interval to supply enough water. Twenty four days to transplanting seedlings into field, seeds were sown in the first bed, there after seven days later, second seeds were sown in the second bed, and the third bed were sown ten days after the second bed was sown. Ten days after sowing the third bed, the set of seedling ages for 24, 17 and 10days was achieved; transplanting was done right away into the field on that same day during the 2020/2021 dry season.

Transplanting

Rice seedlings were transplanted according to treatments (10, 17 and 24 days after sowing) at spacing of 20x20cm in the plots.

Irrigation

Surface Irrigation method was done at an interval of three days to fill the basin which was increased to two days when the evapo-transpiration increased.

Manual Weeding

Hand weeding was done using hoe at 4 and 8Weeks after transplanting (WAT) according to treatment and at 6 WAT supplemental hoe weeding was done on first rates or lowest rates of each of the herbicides. Weeds were collected using (50 x50) cm^2 Quadrat prior to the weeding. The weeds were washed cleaned identified into species, air dried and fresh weight was recorded and subsequently oven dried at 70 ^{0}C weighed until a constant weed dry matter weight was achieved, while weed dry matter from chemical weed control treatments was taken at harvest.

Fertilizer Application

Application of 120:50:50 kg ha^{-1} NPK was done in split doses. The first half application of N (50 kg), and full dose of P_2O_5 and K_2O (50 kg) was applied at the basal stage. The second half of N was applied at maximum tiller stage and at panicle initiation stage using urea (46%) as source.

Herbicide Application

Rates of bracer; 0.250 + Hoe weeding at 6 WAT, 0.275, 0.300 and 0.325L/ha and Bracerplus; 0.129 + Hoe weeding at 6 WAT, 0.142, 0.155 and 0.168 L/ha, Nomineegold at 0.200 + Hoe weeding at 6 WAT, 0.300, 0.400 and 0.500 L/ha respectively, according to treatment were applied at 2-weeks after transplanting using 15 L knapsack sprayer. Application was done once only during the cultivation period. (However the first rates of the herbicide treatment were followed by hoe weeding at 6 WAT after application of the herbicides). The application was done when the soil was saturated with water but not flooded. This was done after calibration of the sprayer to avoid wastage of the herbicide. A day after application of the herbicide, the soil was flooded for 2–3 days according to the herbicide manufacturers' regulations to boost the weed control efficiency of the chemicals.

Harvesting

The crops were harvested at maturity when the entire plants have dried. The plants within the net plot were cut at ground level and bundled into sheaves. Each net plot harvested was threshed by putting into polythene sack and beating with sticks. The paddy collected was threshed, winnowed, cleaned and sun dried.

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Weighing instruments

Rice panicles and oven-dried weed dry matter was weighed using sensitive electronic weighing balance (model XY300-2c) while oven-dried rice straw was weighed using Top loading mettle-P 1210 weighing balance. Digital and temperature adjustable electronic oven was also used for oven-drying weed and rice crop dry matter.

Data Collection

Observation for Weed Parameters

Weed cover score

Weed cover score was taken from each plot on visual rating of 0 to 5, where 0 was given to clean and weed free plots and 5 to those with complete weed cover (Adeosun, 1999). A (50x50) cm^2 quadrat was used to assess weed cover score by placing the quadrat in the net plot. Assessment features of the weed plants that was used for scoring was canopy spread and weediness of the plots.

Weed dry Matter

Weed dry matter was taken at physiological maturity before harvesting to determine weed biomass. The weed samples collected were identified separated into weed species with the aid of a handbook of weed by Akobundu and Agyakwa (1987) oven dried at 70^0C to a constant weight and weighed to obtain the weed dry matter.

Observation for Yield contributing characteristics of rice

Length and weight of panicle

The length and weight of 5 sampled panicles was taken from five hills of each plot just before harvesting, and means were calculated.

Number and weight of grains per panicle

Panicle was weighed in an electronic balance by taking the panicles from five hills of each plot just before harvesting. At the same time numbers of filled and unfilled grains was counted to determine the number of filled grains per panicle.

Sterility percentage

Total unfilled grains per panicle was obtained in the panicles from five hills and this information was used to calculate sterility percentage as per the following formula.

Sterility percent = $\frac{Number\ of\ unfilled\ grains}{Total\ number\ of\ grains}\ x\ 100$

1000- grain weight (g)

A randomly selected 1000 seeds was collected from each plot and weighed using a mettler-P 1210 weighing balance.

Harvest Index

Harvest index (HI) was computed by dividing grain yield with the biological yield (total dry matter yield) as per the following formula:

$$HI\% = \frac{Grain\ yield}{grain\ yield + straw\ yield}\ x\ 100$$

Days to 50% booting

Days to 50% booting was determined from each plot by counting the number of days from transplanting, whereby 50% of plants attained booting stage.

Days to 50% heading

Days to 50% heading was determined from each plot by counting the number of days from transplanting to the time that 50% of plants attained heading stage.

Days to 50% maturity

Days to 50% maturity was determined from each plot by counting the number of days from transplanting to the time that 50% of plants attained maturity stage.

Spikelet per spike

Number of spikelet per spike was determined from five sampled panicles in the net plot from each plot and the average recorded

Productive tillers

Productive tillers was determined from five sampled plants in the net plot from each plot and the average recorded. The feature to be considered include viable panicles borne by the tiller that has a direct bearing with the productivity of the plant.

Filled grains per spike

The number of filled grains per spike was determined from five sampled panicles in the net plot from each plot and the average recorded.

Primary spikelet per spike

The number of Primary spikelet per spike was determined from five sampled panicles in the net plot from each plot and the average recorded and the average recorded.

Secondary spikelet per spike

The number of Secondary spikelet per spike was determined from five sampled panicles in the net plot from each plot and the average recorded.

Grain yield (Kg ha^{-1})

Grain weight was determined from the net plot of each plot after harvest. It will be expressed in kilogram ha^{-1}.

Data Analysis

Data generated was subjected to analysis of variance procedure (ANOVA) as described by Steel and Torrie (1984) and differences between treatment means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability as described by Gomez and Gomez (1984). The relationships between characters was determined through simple correlation analysis as described by Little and Hills (1978).

RESULTS

Correlation analysis in 2021

The result of correlation analysis between rice grain yield, growth and weed parameters in 2021 dry season is shown in table 1 below. Rice grain weakly but positively and significantly correlates with crop height at 12WAT (r = 0.204*), it also weakly, positively, and significantly correlates with Leaf area at 12 WAT (r = 0.333**). The grain yield also moderately, positively and significantly correlates with straw yield (r = 0.705*), at harvest; it also weakly negatively correlates with panicle length (r = -0.019^{ns}).The grain yield weakly but positively and significantly correlates with 1000 grains weight (r = 0.200*), and weed control efficiency (r = 0.317*), but in contrast the rice grain yield negatively but significantly correlates with weed density (r = -0.272*) and weed dry weight (r = -0.272*). Crop height also significantly positively and weakly correlates with weed control efficiency (r = 0.412**). Rice crop height also correlates positively, significantly and weakly with leaf area at 12WAT (r = 0.394*) and leaf area index at 12 WAT (r = 0.270*). Leaf area at 12WAT moderately positively and significantly correlates with leaf area index (r = 0.684**). Leaf area index at 12 WAT weakly but positively and significantly correlates with straw yield at harvest (r = 0.338**), weed control efficiency (r = 0.295*) but negatively and weakly correlates with weed density (r = - 0.250) and weed dry weight (r = - 0.247*) at harvest. Straw yield weakly but positively correlates with 1000 grains weight (r = 0.365*) and weed control efficiency (r = 0.417**), but contrastingly correlates negatively weakly and significantly to weed density (r = - 0.415**) and weed dry weight (r = - 0.416**). Weed control efficiency strongly but negatively and significantly correlates to both weed density (r = - 0.841*) and weed dry weight (r = - 0.846**), while weed density strongly, positively and significantly correlates with weed dry weight (r = 0.997**).

Correlation analysis in 2022

The result of correlation analysis between Rice yield growth and weed parameters is shown in Table 41. Grain yield weakly, positively and significantly correlates with plant height (r= 0.204*), grain yield weakly moderately positively correlates with leaf area (r=0.694**), grain yield correlates with straw yield weakly, positively and significantly (r=0.338**). The relationship between yield and weed control efficiency was significant positive but weak (r=0.317**). Weed density at 12 WAT weakly, negatively correlates with yield. (r=0.355**). Weed control efficiency positively, significantly but weakly correlates with leaf area index at 12 WAT. (r=0.295*). Weed density significantly, moderately but negatively correlates with panicle weight (r= -0.415**). Weed dry matter negatively, strongly and significantly correlates with panicle weight (r= - 0.846**). Weed dry matter negatively, weakly but significantly correlates with leaf area index (r = -0.249**). Weed density negatively, weakly but significantly correlates with leaf area index (r = -0.250**). 1000 grains weight positively, significantly but weakly correlates with grain yield (r=200*). Grain yield positively weakly but significantly correlates with leaf area index at 12 WAT (r= 0.333**).

CONCLUSION

Based on the results obtained positive and significant correlation was observed between like (crop and yield parameters) while significant and negative correlation exists between Crop or yield and weed (contrasting) parameters. This confirms the negative relationship between crop and weed or yield and weed parameters.

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RECOMMENDATION

It is recommended that weed growth should not be allowed to outweigh crop and yield production to avoid economic loss.

Table 1: The effects of weed control methods and age of seedling on weed cover score at 6, 9 and 12 WAT in dry seasons of 2021, and 2022.

		Weed cover score					
		2021			2022		
		6	9	12	6	9	12
Weed Control Methods (W)	Rate (kg.a.i.ha^{-1})						
Bracer+ h/w at 6 WAT	0.025	3.33a	1.56ef	1.56c	2.22b	3.00ab	2.00ab
Bracer	0.027	4.33a	2.67cde	2.33abc	4.22a	3.00ab	2.56ab
Bracer	0.030	1.88b	3.33bc	2.11bc	3.67ab	2.56ab	2.78ab
Bracer	0.032	4.22a	2.78cd	2.11bc	3.00ab	2.78ab	2.78ab
Bracerplus + h/w at 6 WAT	0.021	3.56a	1.44f	1.89bc	4.11a	1.78ab	2.56ab
Bracerplus	0.023	3.89a	2.89cd	2.11bc	4.00a	1.33b	2.56ab
Bracerplus	0.025	4.33a	3.00cd	2.00bc	3.33ab	1.78b	2.56ab
Bracerplus	0.027	3.67a	4.33ab	2.22bc	2.89ab	2.67ab	2.44ab
Nomineegold + h/w at 6 WAT	0.020	3.11ab	1.44f	2.44ab	4.11a	2.67ab	3.00ab
Nomineegold	0.030	3.67a	4.55a	2.33a	4.11a	2.78ab	3.89a
Nomineegold	0.040	4.37ab	3.00cd	2.22bc	4.22a	4.11a	4.00a
Nomineegold	0.050	4.33a	2.67cde	2.67ab	4.33a	2.67b	3.89a
Weeding at 4 and 8 WAT	-	3.89a	2.00def	2.67ab	3.89a	4.00a	3.93a
Weedy check	-	4.44a	4.89a	3.11a	4.44a	4.22a	4.33a
SE$\pm$		**0.396**	**0.356**	**0.289**	**0.504**	**0.502**	**0.389**
Age of seedling (S)							
10-day old		3.85	2.92	2.45a	3.97	3.04	2.30
17-day old		3.90	2.92	2.19ab	3.64	2.67	2.38
24-day old		3.61	2.83	2.17b	3.64	2.71	2.26
SE$\pm$		**0.183**	**0.165**	**0.134**	**0.233**	**0.232**	**0.180**
Interaction WXS		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter(s) in a treatment group are not significantly different at $p \leq 0.05$ NS= Not significant, WAT = Weeks after transplanting

Table 2. The effect of weed control methods and age of seedling on Weed Control Efficiency in 2021, 2022 dry seasons and when combined.

		Weed Control Efficiency		
		2021	**2022**	**Combined**
Weed control methods(W)	**Rate (kg.a.i.ha^{-1})**			
Bracer + h/w at 6WAT	0.025	84.30a	83.71a	84.00a
Bracer	0.027	53.82de	56.60dc	55.21f
Bracer	0.030	74.34abc	76.58ab	75.45bcd
Bracer	0.032	65.60bcd	69.23abcd	67.42de
Bracerplus + h/w at 6WAT	0.021	89.64a	87.25a	88.45a
Bracerplus	0.023	72.78abc	73.08abc	79.26abcd
Bracerplus	0.025	86.60a	86.22a	86.41a
Bracerplus	0.027	78.02ab	80.70a	79.26abcd
Nomineegold+h/w at 6WAT	0.020	88.99a	78.49a	83.74a
Nomineegold	0.030	60.97cde	60.85bcd	60.91ef
Nomineegold	0.040	74.67abc	75.78ab	75.22bcd
Nomineegold	0.050	81.04a	87.19a	80.87abc
Weeding at 4 and 8 WAT	-	54.97d	52.95d	50.46f
Weedy check	-	0.00f	0.00e	0.00g
SE±		**1.378**	**5.463**	**5.103**
Age of seedling (S)				
10-day old	-	64.45b	65.64b	65.08b
17-day old	-	73.46a	73.41a	73.47a
24-day old	-	67.53ab	68.09ab	67.84b
SE±		**0.638**	**2.529**	**2.362**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at p≤0.05 NS= Not significant, WAT = Weeks after transplanting.

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Table 3: Effect of weed control methods and age of seedling on Weed dry Matter at harvest in dry seasons of 2021, 2022 and when combined.

		Weed dry Matter (Ton ha^{-1})		
		2021	2022	Combined
Weed control methods(W)	Rate (kg.a.i.ha^{-1})			
Bracer + h/w at 6WAT	0.025	0.0009d	0.0017cde	0.0013cd
Bracer	0.027	0.0031b	0.0030bc	0.0031b
Bracer	0.030	0.0015cd	0.0014de	0.0015cd
Bracer	0.032	0.0025bc	0.0024bcd	0.0025b
Bracerplus + h/w at 6WAT	0.021	0.0005d	0.0011de	0.0009cd
Bracerplus	0.023	0.0016cd	0.0017cde	0.0016b
Bracerplus	0.025	0.0006d	0.0006e	0.0006d
Bracerplus	0.027	0.0030b	0.0033b	0.0032b
Nomineegold+h/w at 6WAT	0.020	0.0013d	0.0016de	0.0014b
Nomineegold	0.030	0.00310b	0.0031b	0.0031b
Nomineegold	0.040	0.0016cd	0.0016de	0.0016b
Nomineegold	0.050	0.0010d	0.0010de	0.0010cd
Weeding at 4 and 8 WAT	-	0.0006d	0.0006e	0.0006d
Weedy check	-	0.0060a	0.0059a	0.0060a
SE+		**0.011**	**0.00044**	**0.00038**
Significance				
Age of seedling (S)				
10-day old	-	0.0022248a	0.0023	0.0022a
17-day old	-	0.0016749b	0.0018	0.0017b
24-day old	-	0.0020826ab	0.0022	0.0021a
SE+		**0.016**	**0.00029**	**0.00146**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT. NS= non significant, WAT = Weeks after transplanting

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Table 4: Simple Correlation Matrix (Coefficient values and their level of significance) showing the relationship between growth, yield and weed parameters in 2021 dry season

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LAI9WAT	1.000														
NAR9WAT	0.250*	1.000													
CGR9WAT	0.045^{ns}	0.817*	1.000												
RGR9WAT	0.292*	0.501*	0.742*	1.000											
NTIL9WAT	0.769*	0.319*	0.149nd	0.408*	1.000										
RGKP	0.136^{ns}	0.198*	0.386*	0.316*	0.275*	1.000									
STRWY	0.132^{ns}	0.222*	0.336*	0.410*	0.291*	0.810*	1.000								
PCLWGT	0.056^{ns}	0.104^{ns}	0.159^{ns}	0.171^{ns}	0.034^{ns}	0.278*	0.266*	1.000							
THGWT	0.194*	0.052^{ns}	0.230*	0.357*	-0.070	0.260*	0.337*	0.219*	1.000						
HI	0.079^{ns}	0.190*	0.192*	0.174*	0.068^{ns}	0.455*	0.040^{ns}	0.097^{ns}	0.046^{ns}	1.000					
WDST	0.100^{ns}	0.004^{ns}	0.183*	0.318*	0.359*	0.397*	0.424*	0.063^{ns}	0.031^{ns}	0.017^{ns}	1.000				
WDM	0.013^{ns}	0/018^{ns}	0.179*	0.174^{ns}	0.265*	0.361*	0.405*	0.195*	0.191*	0.032^{ns}	0.491*	1.000			
WCE	0.023^{ns}	0.005^{ns}	0.171^{ns}	0.237*	0.296*	0.335*	0.394*	0.183*	0.183*	0.022^{ns}	0.512*	0..904*	1.000		
BLVD3WAT	0.058^{ns}	0.048^{ns}	0.179*	0.280*	0.130^{ns}	0.417*	0.386*	0.110^{ns}	0.139^{ns}	0.064^{ns}	0.780*	0.463*	0.456*	1.000	
GRSLV3WAT	0.167^{ns}	0.059^{ns}	0.175*	0.348*	-0.437*	-0.448*	-0.479*	-0.170^{ns}	-0.035^{ns}	-0.050^{ns}	0.860*	0.467*	0.477*	0.697*	1.000

*= Significance only at 5% and Ns + Not significant at 5%, 1. LAI9WAT = Leaf area index at nine weeks after transplanting, 2. NAR9WAT = Net assimilation rate, 3. CGR9WAT = Crop growth rate at nine weeks after transplanting, 4. RGR9WAT = Relative growth rate at nine weeks after transplanting, 5. NTIL9WAT = Number of tillers at nine weeks after transplanting, 6. Rice grain in kilogram per hectare, 7. STRWY = Straw yield (crop dry matter CDM), 8. PCLWGT = Panicle weight, 9. THGWT = One Thousand grain weight, 10. HI = Harvest index, 11. WDST = Weed density at harvest, 12. WDM = Weed dry matter at harvest, 13. WCE = Weed control efficiency, 14 BLVD3WAT = Number of broad leaved weeds at three weeks after transplanting, 15, GRSLV3WAT = number of Grass weeds at three weeks after transplanting.

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Table 5 Simple Correlation Matrix (Coefficient values and their level of significance) showing the relationship between growth, yield and weed parameters in 2022 dry season.

Parameters	1	2	3	4	5	6	7	8	9	10	11
Grain yield	1.000										
Plant height	0.204*	1.000									
Leaf area	0.061	0.270	1.000								
LAI12wat	0.333**	0.394**	0.694	1.000							
Shoot dry weight	-0.731	00.064	0.071	-0.029	1.000						
STRW	0.705*	0.166	0.058	0.338**	-0.136	1.000					
PCLWGT	0.019	-0.41	0.066	0.043	-0.041	-0.076	1.000				
1000GRWGT	0.200*	0.026	-0.246**	0.008	-0.113	0.365*	-0.123	1.000			
WCE %	0.317**	0.416	0.115	0.295	0.069	0.417	0.010	0.112	1.000		
WDST12WAT	-0.355**	-0.272**	-0.081	-0.250	0.074	-0.415	-0.078	-0.111	-0.847**	1.000	
Wtons/ha	-0.357**	-0.272**	-0.082	-0.249**	0.075	-0.415	0.078	-0.111	-0.846**	0.999**	1.000

Grain yield, 2 Plant height, 3. Leaf area at 12WAT, 4 Leaf area index at 12WAT, 5 Shoot dry weight 6 Straw weight, 7 Panicle weight, 8 1000 grain weight, 9 Weed control efficiency, 10 Weed density at 12WAT, 11 Weed dry weight

Table 7: Effect of weed control methods and age of seedling on plant height of rice in 2021 and 2022 dry seasons.

		Plant height (cm)					
		2021			2022		
		6WAT	9WAT	12WAT	6WAT	9WAT	12WAT
Weed control methods(W)	**Rate (Kg a.i. ha^{-1})**						
Bracer+h/w + 6WAT	0.025	11.74cde	23.80ab	55.53ab	14.10a	22.89bc	48.69abc
Bracer	0.027	16.89a	23.21ab	54.16ab	13.00cde	26.96ab	50.94ab
Bracer	0.030	14.34bc	20.94abcd	48.87abcd	13.53bcd	23.40bcd	47.54abcd
Bracer	0.032	12.75bcd	20.13abcd	46.98abcd	13.28cde	24.22abc	48.35abc
B/plus + h/w at 6WAT	0.021	15.03ab	22.01abc	51.30abc	13.72bcd	23.40bcd	47.76abc
Bracerplus	0.023	14.41bc	25.06a	58.46a	14.93a	21.60cd	46.57bcd
Bracerplus	0.025	12.86bcd	21.34abc	49.80abc	14.20b	20.83cd	45.43cd
Bracerplus	0.027	10.70de	18.77bcd	43.79bcd	12.19de	24.22abc	47.95abc
Nomineegold+h/w at 6WAT	0.020	12.55bcd	18.79bcd	43.84bcd	13.78bcd	22.43cd	46.83bcd
Nomineegold	0.030	11.91cde	18.58bcd	43.35bcd	13.30bcde	21.78cd	45.33cd
Nomineegold	0.040	11.13de	17.29cd	40.34bcd	13.30bcde	19.33d	43.49d
Nomineegold	0.050	12.36bcd	23.40ab	55.60ab	13.35bcde	27.72a	51.89a
Weeding at 4 and 8 WAT	-	12.92bcd	17.52cd	40.88bc	12.58cde	21.18cd	44.97cd
Weedy check	-	9.64e	15.51d	36.19d	11.05e	12.96e	34.53e
SE±		**0.525**	**0.756**	**1.156**	**0.900**	**1.333**	**1.352**
Age of seedling (S)							
10-day old		12.21b	19.33	45.29	12.98b	20.27c	44.27c
17-day old		12.73b	20.60	48.07	13.10b	22.27b	46.33b
24-day old		13.03a	21.42	49.99	14.28a	24.10a	48.74a
SE±		**0.243**	**0.350**	**0,534**	**0.416**	**0.617**	**0.621**
Interaction WXS		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT NS= non significant
Kg = Kilogram; WAT = weeks after transplanting; cm = centimeter; a.i. = active ingredient.

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Table 6 : Effect of weed control methods and age of seedling on number of tillers per plant of rice at 6, 9, and 12 WAT in 2021 and 2022 dry seasons.

		Number of tillers per plant			Number of tillers per plant		
		2021			**2022**		
Weed control methods(W)	**Rate (Kg a.i. ha^{-1})**	**6WAT**	**9WAT**	**12WAT**	**6WAT**	**9WAT**	**12WAT**
Bracer + h/w + 6WAT	0.025	13.52abc	15.67bc	20.89bc	8.44abcd	12.22cd	12.41cd
Bracer	0.027	13.88abc	16.64ab	18.52bcd	9.33cde	13.00bcd	22.70abc
Bracer	0.030	11.74abc	13.56bcd	18.07bcd	8.78cde	15.33ab	22.85abc
Bracer	0.032	16.22ab	17.98a	21.63bc	4.56bcd	15.11abc	25.67a
B/plus + h/w at 6WAT	0.021	15.46ab	21.33a	28.44a	10.78a	14.22abcd	21.89abcd
Bracerplus	0.023	16.18ab	16.33ab	21.78bc	8.78cde	12.67bcd	22.52abc
Bracerplus	0.025	11.92abc	13.92bcd	14.96cd	8.44def	12.80bcd	20.74abcd
Bracerplus	0.027	10.00bc	10.33de	13.78de	8.44def	13.67abcd	17.59cd
Nomineegold + h/w at 6WAT	0.020	14.58ab	17.33a	17.78bcd	9.89abc	13.89abcd	19.74bcd
Nomineegold	0.030	14.09ab	16.33ab	15.11cd	8.22ef	12.22abcd	18.29cd
Nomineegold	0.040	13.43abc	14.22bcd	16.30cd	10.44ab	16.78a	23.45ab
Nomineegold	0.050	13.27abc	15.78bc	21.04bc	9.56bcd	13.67abcd	23.74ab
Weeding at 4 and 8 WAT	-	13.83abc	17.67a	23.56ab	8.67de	12.44cd	23.96ab
Weedy check	-	5.68e	7.31c	7.58e	2.44f	5.560d	7.22e
SE±		**2.240**	**1.620**	**2.159**	**0.823**	**1.177**	**1.629**
Age of seedling (S)							
10-day old		14.70	15.57	19.43a	9.17	13.50	22.21a
17-day old		14.81	15.92	18.57ab	8.83	13.67	20.61ab
24-day old		11.20	13.21	17.62b	9.17	13.67	20.76b
SE±		**0.377**	**0.340**	**0.393**	**0.381**	**0.545**	**0.754**
Interaction WXS		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT NS= non significant
Kg = Kilogram; WAT = weeks after transplanting; a.i. = active ingredient.

Table 7: Effect of weed control methods and age of seedling on 1000 grain weight of rice in dry seasons of 2021, 2022 and when combined.

		1000 grain weight (g)		
		2021	2022	Combined
Weed control methods(W)	Rate (kg.a.i.ha^{-1})			
Bracer+ h/w at 6WAT	0.025	26.67ab	25.67a	26.17a
Bracer	0.027	20.67c	20.11bc	20.39de
Bracer	0.030	23.78abc	22.11abc	22.94abcde
Bracer	0.032	22.33abc	20.67bc	21.50cde
Bracerplus + h/w at 6WAT	0.021	27.00a	22.89abc	24.67abc
Bracerplus	0.023	23.79abc	20.00bc	21.89cde
Bracerplus	0.025	26.44ab	24.67ab	25.83ab
Bracerplus	0.027	23,00abc	21.44abc	22.22bcde
Nomineegold+h/w at 6WAT	0.020	24.33abc	21.44abc	22.89abcde
Nomineegold	0.030	24.44abc	22.00abc	23..22abcd
Nomineegold	0.040	26.22ab	24.00ab	25.11abc
Nomineegold	0.050	25.00abc	21.44abc	23.22abcd
Weeding at 4 and 8 WAT	-	21.78bc	19.22bc	20.50de
Weedy check	-	20.67c	18.33c	19.50e
SE+		**0.706**	**1.652**	**1.112**
Age of seedling (S)				
10-day old	-	24.57	21.69	23.13
17-day old	-	23.40	21.50	22.45
24-day old	-	24.04	21.95	23.00
SE+		**0.326**	**0.764**	**0.515**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT. NS= non significant

Table 8 Effect of weed control methods and age of seedling on grain yield in dry seasons of 2021, 2022 and when combined.

	Rate	Grain yield (Kgha^{-1})		
	(kg.a.i.ha^{-1})	2021	2022	Combined
Weed control methods Table **(W)**				
Bracer + h/w at 6WAT	0.025	4066.20ab	4794.30a	4430.25a
Bracer	0.027	3340.50b	3307.20ab	3323.85cde
Bracer	0.030	3340.50b	3274.80ab	3307.65abc
Bracer	0.032	3234.60b	4039.80abc	3637.20abcd
Bracerplus + h/w at 6WAT	0.021	4902.30a	3995.40ab	4448.85a
Bracerplus	0.023	3246.30b	2840.10bcd	3043.20cde
Bracerplus	0.025	3240.30b	3343.20bc	3291.75bcd
Bracerplus	0.027	1589.80c	3545.40ab	2567.60ef
Nomineegold + h/w at 6WAT	0.020	2800.50bc	2746.20abc	2773.35cde
Nomineegold	0.030	2659.80bc	2076.90cde	2368.35cde
Nomineegold	0.040	3932.10ab	4114.20a	4023.15abc
Nomineegold	0.050	4188.60ab	4160.70a	4174.65a
Weeding at 4 and 8 WAT	-	1892.10c	1920.00bc	1906.05de

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Weedy check	-	477.90e	319.80e	398.85f
SE+		**75.681**	**65.739**	**70.710**
Age of seedling (S)				
10-day old	-	3600.60a	3375.90a	3488.25a
17-day old	-	2916.90b	2952.30b	2934.60b
24-day old	-	2697.00c	2784.00c	2740.50c
SE+		**35.037**	**30.434**	**32.735**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT.

NS= non significant

Table 9 Effect of weed control methods and age of seedling on Crop dry matter in dry seasons of 2021, 2022 and when combined.

	Rate	Crop dry matter (t ha^{-1})		
	(kg.a.i.ha^{-1})	2021	2022	Combined
Weed control methods(W)				
Bracer + h/w at 6WAT	0.025	0.160ab	0.155a	0.164a
Bracer	0.027	0.107abc	0.108abcd	0.108bc
Bracer	0.030	0.127abc	0.129abc	0.121ab
Bracer	0.032	0.127abc	0.135ab	0.131ab
Bracerplus + h/w at 6WAT	0.021	0.172a	0.156a	0.164a
Bracerplus	0.023	0.105bc	0.045de	0.035bd
Bracerplus	0.025	0.122abc	0.120abc	0.121ab
Bracerplus	0.027	0.038de	0.126abc	0.096bc
Nomineegold + h/w at 6WAT	0.020	0.110abc	0.109abcd	0.109bc
Nomineegold	0.030	0.064cde	0.063cde	0.064cd
Nomineegold	0.040	0.134ab	0.129abc	0.127ab
Nomineegold	0.050	0.129abc	0.142ab	0.138ab
Weeding at 4 and 8 WAT	-	0.095bcd	0.093abcd	0.094bc
Weedy check	-	0.026e	0.026e	0.026d
SE+		**0.081**	**0.020**	**0.022**
Age of seedling (S)				
10-day old	-	0.1367a	0.126a	0.133a
17-day old	-	0.1025b	0.102ab	0.102b
24-day old	-	0.0868b	0.092b	0.089b
SE+		**0.038**	**0.009**	**0.010**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT.

NS= non significant

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Table 10 : Effect of weed control methods and age of seedling on harvest index in 2021, 2022 dry seasons and when combined.

	Rate	Harvest index (%)		
	(kg.a.i.ha^{-1})	2021	2022	Combined
Weed control methods(W)				
Bracer+ h/w at 6WAT	0.025	44.22abc	44.96abcd	44.77abc
Bracer	0.027	43.21abc	46.33abcd	45.39ab
Bracer	0.030	42.04abc	44.51abcd	43.69abc
Bracer	0.032	45.51abc	53.65ab	53.60a
Bracerplus + h/w at 6WAT	0.021	53.56a	45.96abcd	43.69ab
Bracerplus	0.023	43.94abc	57.21a	50.72a
Bracerplus	0.025	42.04abc	45.27abcd	43.04abc
Bracerplus	0.027	35.70c	56.93a	46.03ab
Nomineegold+h/w at 6WAT	0.020	37.67bc	38.20bcd	37.94bc
Nomineegold	0.030	49.79abc	49.94abc	50.72a
Nomineegold	0.040	45.14abc	42.24abcd	44.18abc
Nomineegold	0.050	52.46ab	52.37abc	52.41a
Weeding at 4 and 8 WAT	-	48.97abc	35.55d	35.07bc
Weedy check	-	34.59c	30.27d	0.32.99c
SE±		**0.125**	**0.526**	**0.099**
Age of seedling (S)				
10-day old	-	39.24b	50.68a	49.52a
17-day old	-	44.92ab	44.33ab	44.63b
24-day old	-	48.35a	42.53b	40.89b
SE±		**0.058**	**0.243**	**0.046**
Interaction WXS		**NS**	NS	NS

Means followed by the same letter(s) in a treatment group are not significantly different at 5% level of significance using DMRT.

NS= non significant

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