Original Research Article

EFFECT OF WEEDING REGIME AND ROW DIRECTION ON GROWTH AND YIELD OF UPLAND RICE IN UGANDA

ABSTRACT

The effects of row direction on growth and productivity of rice, efficacy of herbicide Butanil-70 herbicide and economics of integrated weed management options in 2 row orientations were evaluated. A completely randomized block design, replicated thrice was adopted with NAMCHE 5 rice variety. The study was conducted during 2021B and 2022B at Ikulwe Research Station in Uganda. We included 12 treatments with 6 weeding regimes namely; Pre- emergence Butanil (PREB) + 1hand hoeing (HH), 2HH), 3HH, PREB + Post emergence Butanil (POEB), weekly weeding till 42 days after emergency and no weeding in east - west (EW) and north - south (NS) row orientation. Nitrogen (100 kg) Phosphorus (60 kg) and Potash (40 kg) fertilizers were applied per hectare. Data were collected on rice height, tillers, leaves, panicles and grains and subjected to ANOVA using 13th edition of Genstat software. Significantly higher parameters were registered in EW than NS direction. Higher growth and yield attributes were recorded during both seasons under 2HH, PREB +1HH, PREB + POEB and 3HH treatments in EW orientation during both seasons. Maximum Benefit Cost Ratios (BCR) and Marginal Rate of returns (MRR) were observed under 2HH and PREB + 1HH in EW row direction. EW orientation however, produced lower leaves and tillers under PREB + POEB and 3HH during 2022B. Weekly weeding (EW) developed lower tillers, panicles and grain yield relative to other EW treatments in 2022. Lower leaves, tillers, panicles and grain yield were recorded under the weedy check (2021 & 2022) and row directions had no influence on growth and yield. Grass biomass was numerically higher under EW than NS direction. Planting upland rice in EW row direction and applying 2HH or PREB + 1HH were the most economical weed management options and recommended in Uganda.

Key words: Butanil, Benefit Cost Ratio, integrated weed management, post-emergence, pre-emergence, weeds

1. INTRODUCTION

Weeds limit the yield in rice production worldwide. Rice has ranked second as a food crop in Uganda for decades. Technologies for weed control in rice do not consider the critical period of weed control; ignore an integrated weed management (IWM) approach and row directions. Rice (*Oryza sativa* L.,) has ranked second to maize as a food crop in Uganda for over two decades (1) and providing 20% of the world's dietary energy supply (2). Over 50% of the world population depends on rice as daily food (3). Given the increasing demand for rice due to an escalating human population and shift from paddy to upland, it is paramount to generate technologies that would enhance the productivity of upland rice. The crop has been characterised with reduction in profits due to decline in productivity which is associated with drought, poor soil fertility coupled with an increase in incidences of weeds, pests and diseases. Despite the increased production, productivity (1.80 MT ha^{-1}) is still declining (1) relative to the attainable potential (5-6 MT ha^{-1}). The yield of rice can be increased with improved cultivation practices like optimum planting time, planting density, fertilizer management, adequate spacing, proper row direction and weed management. Among the limiting factors, the infestation of weed is one of the most important constraints in the cultivation of rice. The effects of weeds on rice are reduced yield and quality mostly due to competition for nutrients, water and sunlight and in upland direct seeded rice yield reductions are as high as 74% (4). Weeds are the greatest yield limiting factor in rice production (5), compete with rice for space, nutrients, air, water and light and thus adversely affect rice growth and yields. Weeds promote pests and disease problems by serving as alternate hosts and reduce efficiency of harvesting. (6) reported losses of 80% in rice yield due to weeds. Higher yield losses due to weeds in upland rice have been observed in Uganda. (7) observed complete rice crop failure. Weed control in transplanted rice by mechanical and cultural means is an expensive method especially at peak periods requiring labor (8). In Uganda, the traditional methods of weed control include hand hoeing and preparatory land tillage. Manual weed control is effective against many weeds but difficult to apply due to scarcity and rising wages of labor and its dependence on prevailing weather conditions (9).

Chemical methods are limited to commercial farmers and include application of pre-emergence and post-emergence herbicides but have proven to effectively control weeds at the correct dosages (10). The production costs therefore increase due to weed control costs. Therefore, use of herbicides integrated with hand hoeing is paramount and gaining popularity. But herbicidal weed controls have some negative impacts on the environment. Yield loss depends upon some variables like magnitude of weed infestation, type of weed species, time of association with crops, fertilization, competitive ability of the variety and cultural management accomplished with control of the pest. (11), reported that the variety NERICA 4 to be more tolerant to weed pressure than other varieties. This may be attributed to allelopathic influence of NERICA rice in weed control (12 & 13), a property that reduces the costs of hand weeding in crop rotation and intercropping systems (14). A number of studies indicate that weed control through both traditional and chemical methods influence plant height, tiller number, crop growth rate, yield attributes and yield of rice (15). Proper row direction produces maximum Leaf Area Index (LAI) and higher light interceptions which influences the tillering, panicle initiation, growth, filling and subsequently the grain yield of rice. (5), reported the east - west (EW) row direction to more effectively control weeds in the rice interow and allow the rice crop to more effectively compete with weeds for the light between the rows. This gives higher growth, yield parameters, grain and biomass yield over north - south (NS) row direction. Improper row orientation affects the physiological activities of rice plant and can reduce potential yield by 15-25% (16). Adjustment of row spacing (17) and direction is necessary to eliminate crops light competition and create suitable micro-climate for obtaining the maximum grain yield of rice through solar radiation and increased photosynthesis. Rice is a C3 plant that uses the C3 pathway in the dark reaction of photosynthesis and use the Calvin cycle. In C3 plants the photosynthesis process occurs when the stomata are open and thus such crops are more efficient in synthesizing metabolites when in EW than NS orientation (17).

In Uganda few studies have attempted to establish the most effective and economical integrated weed management options in upland rice ecosystems and research on row direction in rice is limited. (18), observed that any weed management approach should be aimed at controlling weeds only during the critical period of weed competition for a more cost effective and eco-friendly weed management. The critical period of weed control is defined as the time period in the crop growth cycle, during which weeds must be controlled to prevent unacceptable yield loss (19). (20), observed the critical period for NERICA rice to be 14-42 days after sowing and weed control before or after that period had negligible effect on rice grain yield. Weed control outside the critical period may not reduce crop yields below acceptable levels and is negligible (8, 5). Adoption of diverse technology like an integrated weed management using hand hoeing and herbicides is essential for weed management because weed communities are highly responsive to management practices (21, 22). (23), found 2HH and Pre-emergence (Atrazine) + 1HH the most cost effective weed control technologies in maize. Therefore this experiment was conducted with major objective of determining the effect of integrated weed control and row direction on growth and yield of upland rice in Uganda with the following specific objectives;

i) To establish the influence of row direction on rice growth and productivity in Uganda
ii) To evaluate the performance of the common pre-emergence and post- emergence herbicide.
iii) To assess the economics feasibility of different integrated weed management options in different row orientations.

2. MATERIALS AND METHODS

2.1 FIELD EXPERIMENT

An experiment was carried out at the National Agricultural Research Organisation (NARO), Ikulwe station in Mayuge District of Uganda during the second rain season of 2021B and 2022B (September-December). The study adopted. of 12 treatments with 6 weeding regimes viz. T1= Pre-emergence, Butanil-70; (PREB) 500 EC @ 2.5 l ha^{-1}, T2 = 2 hand hoeing (HH) @ 14 days after emergence (DAE) & 28 DAE, T3= 3HH @ 14, 28 & 42 DAE, T4= PREB, 500 EC @ 1.0 l ha^{-1} & post-emergence, Butanil-70 (POEB) @ 28 DAE, T5=Weekly weeding up to 42 DAE, T6= Control (No weeding) and two row directions, viz. S1= East-West row direction, S2 =North-South row direction. Similar seeding density (200 rice seeds m^{-2} or 50 kg ha^{-1}.were adopted. Butanil-70 (Butachlor + propanil) herbicide used in the experiment is both a pre-and post-emergence type. The experiment was laid out in a randomized complete block design replicated thrice. Thus the total number of unit plots was 36 each measuring 4 × 5 m. The distance between unit plots and replications were 1 m and 1 m, respectively. NAMCHE 5 rice variety was used and the seeds were collected from Pride project, at Namulonge Uganda. Rice seeds were planted by drill method at a spacing of 45 cm between rows and 12.5 cm within the row (1 seed). Fertilizers were applied in the plots @ 100 kg ha^{-1}, 60 kg ha^{-1}, 40 kg ha^{-1} of N, P_2O_5 and K_2O in the form of Urea, Triple Super Phosphate and Muriate of Potash (MP), respectively. The entire amount of TSP and MP were applied as basal at planting and Urea was top dressed in three equal splits at 15 DAE, 30 DAE (tillering stage) & 45DAE (panicle initiation stage). At 21 DAE 10 plants were selected and tagged for biometric data measurements on plant height, number of tillers, number of leaves, leaf length and width. The plant height was taken from the base of the plant to the base of the flag leaf at panicle initiation stage and the longest and widest parts of the leaves were taken on the tagged plants. Prior to harvest 10 plants per plot will be selected randomly (excluding border hills). At harvest plants within a quadrant were harvested, dried on a cemented floor and the panicles were carefully removed, threshed, cleaned and further dried in the Agronomy Field Laboratory to record the data on grain yield. Weeds in a 1 m square quadrat were completely cut at the ground level and oven dried at 80 ^{o}C for 12 hours till constant weight and dry biomass was determined. Data was collected on the yield parameters namely panicles per plant, filled panicles, empty panicles and grains per panicle. All data collected was subjected to analysis of variance using 13th edition of Genstat software. Fischer's least significant difference (LSD) test at $P< .05$ was used to separate treatment.

2.2 Rainfall during 2021B and 2022B

The data on rainfall received during the growing season (September-December) 2021B and 2022B) and measure at Ikulwe Research station is indicated in Table 1. The weekly and monthly total rainfall during 2022B was higher than during 2021B. The total seasonal rainfall during 2022B was higher (850.6 mm) than during the cropping season (652.0 mm) of 2021B.

Table 1 Rainfall received during 2021B and 2022B

Month		2021B		2022B	
September	**Week**	**Weekly rainfall (mm)**	**Weekly total rainfall (mm)**	**Weekly total rainfall (mm)**	**Weekly total rainfall (mm)**

	1	7.3	141.7	110.1	222.9
	2	35.4		34.3	
	3	40.0		48.9	
	4	59		29.6	
October					
	1	86.4	223.0	76.2	228.7
	2	27.1		39.6	
	3	97.9		96.5	
	4	9.6		16.4	
November					
	1	18.9	155.1	19.2	155.1
	2	3.7		18.8	
	3	28.9		13.6	
	4	103.6		103.5	
December					
	1	25.8	132.2	15	243.9
	2	42		106.7	
	3	63.9		90.3	
	4	0.5		31.9	
Total			**652.0**		**850.6**

2.3 ECONOMIC ANALYSIS

Economic analysis of various treatments was determined according to the method by (24). According to this method the fixed cost (non-treatment) comprised rice seed, fertilisers and machinery inputs and variable costs were the treatment expenditure. A 10% reduction in yield (adjusted yield) is made for economic analysis, considering losses due to harvesting and transportation from the field to the market (25). Net benefits were obtained by subtracting every variable cost from the gross income. The calculations were in local currency (Uganda Shillings). For calculation of costs 1 US dollar was equivalent to 3,500 Uganda shillings (Ush).

2.3.1 Benefit cost ratio

The Benefit cost ratio provides a competitive advantage and was determined by the formulae:

$$\text{BCR} = \frac{\textit{Gross income (Ush)}}{\textit{Gross cost (Ush)}}$$

2.3.2 Marginal rate of returns (MRR%)

The marginal analysis determines the dominance of a treatment on the preceding treatment and estimated through ordering the treatments in increasing order of returns. Marginal cost is the change in cost when an additional unit of a good or service is produced. It is the additional cost you incur when you produce additional units of a product. Marginal benefit is the difference you receive when you make a different choice. The MRR was calculated using the following formula:

$$\text{MRR (\%)} = \frac{\textit{marginal net benefit (Ush)}}{\textit{marginal cost (Ush)}}$$

3. RESULTS

3.1 GROWTH PARAMETERS AND YIELD FOR RICE DURING 2021B

Data on growth parameters and yield for NAMCHE 5 planted in EW and NS directions under different Integrated Weed Management Options at Ikulwe station during 2021B are presented in Table 2. Mean number of leaves, plant height, number of tillers and filled panicles per plant were significant. All treatments with an EW orientation produced significantly ($P< .05$), higher growth and yield attributes than rice in the NS row directions. 2HH, Butanil as pre-PREB + 1HH, PREB + POEB and 3HH in the EW direction produced higher mean numbers of leaves (27-28 leaves), plant height (65-70 cm), number of tillers (5-6 tillers), total panicles (4-5 panicles) per plant and significantly ($P< .05$), higher rice grain yield than other treatments. Weed free conditions under weekly weeding up to 42 DAE in the EW row direction significantly ($P<0.05$), reduced the yield parameters to 4.5 tillers, 3.6 panicles and the rice grain yield to 1293 kg Ha^{-1} relative to the other treatments in similar row orientation. Weekly weeding (EW) however, recorded similar number of leaves and plant height to the other treatments. Treatments in NS row direction except weekly weeding influenced the rice crop and produced significantly lower ($P<.05$), leaves (19-23 leaves) than rice in the EW row direction. High numbers of panicles per plant than other NS treatments and numerically higher (1250 Kg Ha^{-1}) rice grain yield amongst treatments were recorded under weekly weeding in the NS row orientation. PREB + POEB, PREB+ 1HH, 2HH and 3HH (NS) produced significantly ($P< .05$), lower number of leaves, tillers and filled panicles per rice plant and grain yield per hectare than treatments in EW row orientation. Lower ($P< .05$); number of leaves (11-12 leaves), number of tillers (2 tillers), panicles (2-3 panicles) and rice grain yield were produced by weedy checks amongst all treatments. Field observations indicated higher grass biomass in the EW than NS direction. However change of row directions under the weedy treatments did not influence the growth and yield of rice.

3.2 GROWTH PARAMETERS FOR RICE DURING 2022B

Data on growth parameters for NAMCHE 5 planted in EW and NS directions under different integrated weed management options at Ikulwe station is indicated in Table 2. A similar trend of observation was made to the data in season 2021B. Data was significant ($P< .05$), for all the treatments except leaf width during 2022B. EW orientation recorded significantly higher ($P< .05$), data than the NS row orientation. Plant height and leaf length under treatments in both EW and NS row directions were at par except under the weedy checks that recorded lower observations. 2HH, PREB + 1 HH besides weekly weeding (EW) recorded significantly ($P< .05$), higher rice growth. PREB + POEB and 3HH recorded lower number of leaves (27 leaves) and number of tillers (5-6 tillers) than other treatments in EW orientation. Weekly weeding treatment in NS row direction recorded high numbers of leaves, and tillers per plant than other NS treatments and numerically high plant height (55.8 cm) and leaf length (44.2 cm) amongst rice in the NS row orientation. 2HH and 3HH in the NS row direction produced rice with numerically high number of leaves, plant height and length of leaves per plant. Weedy checks under the EW and NS row directions recorded the lowest plant height (8 -10 cm), number of tillers (2-3 tillers) and leaf length amongst all the treatments.

Table 2 Growth parameters and yield for NAMCHE 5 planted in EW and NS directions under different integrated weed management options at Ikulwe station during 2021B

Treatment	Data per plant				Grain yield ($Kg\ Ha^{-1}$)
	Leaves	Height (cm)	Tillers	Filled Panicles	
2HH (EW)	27.7a	64.8a	5.8a	4.8a	2343a
PREB + 1 HH (EW)	28.3a	67.9a	5.7a	4.8a	2255a
PREB + POEB (EW)	26.9a	69.7a	5.0a	4.4a	2007a
3HH (EW)	26.7a	64.8a	5.1a	4.0a	1893a
Weekly weeding (EW)	26.6a	64.7a	4.5b	3.6b	1293b
Weekly weeding (NS)	26.8a	57.3b	4.2b	3.8a	1250b
PREB + POEB (NS)	22.6b	61.0b	4.0b	3.5b	1190b
PREB+ 1HH (NS)	22.3b	59.1b	3.7b	3.3b	1210b
2HH (NS)	20.7b	55.1b	3.8b	3.5b	810b
3HH (NS)	18.9b	53.8c	3.3b	3.5b	633b
WEEDY (EW)	10.6c	61.1b	2.0c	2.4c	343c
WEEDY (NS)	12.1c	56.5b	1.6c	2.3c	326c
P = (.005)	<0.001	0.001	<0.001	0.002	<0.001
LSD	8.2	7.07	1.20	1.12	997.4
(CV %)	19.7	6.1	21.7	16.7	44.4

Values with different letters in a column are significantly different at P≤0.05, HH = hand hoeing, EW = east - west, NS = north - south, PREB = pre- emergence Butanil, POEB = post emergence Butanil, $Kg\ Ha^{-1}$ = kilograms per hectare

3.3 YIELD PARAMETERS AND YIELD OF RICE DURING 2022B

Data on yield parameters and yield of rice planted in EW and NS row directions is presented in Table 3. All weed control treatments with rice planted in the EW row direction produced significantly (*P*< .005) high (4 - 5 panicles) per plant, longer panicles, and rice grain yield. 2HH, PREB + 1HH and 3HH in the EW row direction gave numerically higher yield parameters and grain yield than all other treatments. Treatments given weekly weeding produced lower grains $panicle^{-1}$ (102 grains) and grain yield (2996 kg ha^{-1}). Treatments given weekly weeding and PREB + POEB in the NS row direction produced short rice panicles. Weedy checks gave lower number of leaves, plant height, number of tillers and shorter leaves than all other treatments.

Table 3a Growth parameters for NAMCHE 5 planted in EW and NS directions under different integrated weed management options at Ikulwe station during 2022B

Treatment	Data per plant

	Leaves	Height (cm)	Tillers	Leaf length (cm)	Leaf width (mm)
2HH (EW)	45.5a	64.8a	9.9a	39.3a	19.6
PREB + 1HH (EW)	37.7a	51.0a	8.0a	37.3a	17.0
Weekly weeding (EW)	41.9a	55.4a	7.5a	39.4a	10.7
PREB + POEB (EW)	27.4b	51.3a	5.3b	43.2a	17.9
3HH (EW)	27.4b	64.8a	6.0b	39.9a	14.3
Weekly weeding (NS)	36.4a	55.8a	8.0a	44.2a	10.7
PREB + POEB (NS)	25.0b	43.5a	4.7b	40.0a	17.0
PREB + 1HH (NS)	26.4b	48.6a	5.8b	37.7a	15.6
2HH (NS)	30.2b	57.2a	4.2b	43.4a	18.5
3HH (NS)	27.6b	60.9a	5.8b	40.8a	17.1
WEEDY (EW)	10.0c	35.0b	3.0c	26.0b	11.2
WEEDY (NS)	7.85c	34.1b	2.4c	25.3b	9.1
P = (.005)	< .001	.004	< .001	< .001	0.68
LSD	9.86	29.6	2.38	7.4	NS
(CV %)	13.1	11.6	13.1	7.3	36.3

Values with different letters in a column are significantly different at P≤0.05, HH = Hand Hoeing, EW = East - West, NS = North – South, PREB = Pre- emergence Butanil, POEB = Post emergence Butanil

3.4 BIOMASS OF WEEDS IN WEEDY (CONTROL) TREATMENTS

Control treatments in the EW orientation produced on average 10 Mt Ha^{-1} compared to a lower weight of 7.5 Mt Ha^{-1} of weeds in the NS row direction.

Table 3b Yield parameters and yield for NAMCHE 5 planted in EW and NS directions under different integrated weed management options at Ikulwe during 2022B

Treatment	Yield parameters	Grain yield

	Panicles plant^{-1}	**Panicle length(cm)**	**Grains/panicle**	**(Kg Ha^{-1})**
2HH (EW)	4.9a	21.2a	115a	4393a
PREB + 1HH (EW)	4.0a	22.5a	117a	4140a
3HH (EW)	3.8a	20.6a	116a	4008a
PREB + POEB (EW)	3.8a	18.4b	110a	3840a
Weekly weeding (EW)	3.8a	19.3a	102b	2996b
2HH (NS)	3.0b	19.2b	92b	2618b
Weekly weeding (NS)	3.0b	16.7c	92b	2987b
PREB + POEB (NS)	3.0b	15.5c	93b	2980b
POEB+ 1HH (NS)	2.7b	18.3b	90b	2476b
3HH (NS)	3.0b	19.3b	92b	2426b
WEEDY (EW)	1.0c	8.5d	11.5c	180c
WEEDY (NS)	1.0c	9.0d	9.5c	75c
P (.005)	<0.001	<0.001	<0.001	<0.001
LSD	1.2	2.0	23.6	1200
(CV %)	16.7	4.5	10.2	22.2

Values with different letters in a column are significantly different at P$\leq$0.05, HH = hand hoeing, EW = east - west, NS = north - south, PREB = pre- emergence Butanil, POEB = post emergence Butanil, Kg Ha^{-1} = kilograms per hectare'

3.5 ECONOMIC ANALYSIS DURING 2022B

3.5.1 Production costs and income

Economic analysis of treatments is indicated in Table 4. Higher gross income, grain yield and adjusted yield were under 2HH and PREB + 1HH in the EW row direction. 3HH (EW) and PREB + POEB (EW) similarly recorded high grain yield and monetary returns. The latter 2 treatment however, had high variable production costs with low net gross income. Highest total variable costs (1,590 Ush per hectare) were observed under the weekly weeding with low grain yield and gross net income.

3.5.2 Benefit cost ratios for weeding regimes in Wand NS directions during 2021A and 2022B

The maximum Benefit Cost Ratios (BCR) was observed in 2HH and PREB + 1HH in the EW row direction during 2021B (Fig. 1) and 2022B (Fig 2). NS orientation recorded lower BCR than EW row treatments. PREB + POEB (EW) and 3HH recorded low BCR.

Table 4 Economic analysis of the treatments

Parameter	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	Remarks
Grain yield (t ha^{-1})	4.84	4.51	4.4	4.18	3.3	0.22	2.86	0.28	0.26	3.3	3.3	0.09	
Adjusted	4.4	4.1	4.0	3.8	3.0	0.2	2.6	2.5	2.4	3.0	3.0	0.08	Tons per ha

yield													**(10% reduction at farm level)**
Gross income	**4,686**	**4,510**	**3,786**	**4,014**	**2,586**	**686**	**1,620**	**2,420**	**1,266**	**2,380**	**2,500**	**652**	**Rice price = 1,500 Ush**
Labor, seed and fertilisers	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**2,070**	**Total labor cost**
Herbicide application costs	**0**	**125**	**0**	**250**	**0**	**0**	**0**	**125**	**0**	**250**	**0**	**0**	**Cost of herbicide + spraying labor**
Weeding, harvesting & processing costs	**400**	**390**	**600**	**0**	**1,200**	**30**	**400**	**200**	**600**	**0**	**1,200**	**30**	**Total weeding costs**
Other variable costs	**190**	**200**	**390**	**640**	**390**	**0**	**190**	**390**	**390**	**390**	**390**	**0**	**Cleaning and handling**
Total Variable costs	**590**	**715**	**990**	**640**	**1,590**	**30**	**590**	**715**	**990**	**640**	**1,590**	**30**	**Ush**
Gross production costs	**2,660**	**2,785**	**3,060**	**2,710**	**3,660**	**2,040**	**2,660**	**2,785**	**3,060**	**2,710**	**3,660**	**2,070**	**Ush**
Net income (Benefits)	**4,686**	**4,510**	**3,786**	**4,014**	**2,586**	**686**	**1,620**	**2,420**	**1,266**	**2,380**	**2,500**	**652**	**Ush per ha**

T_1 = 2HH (EW)**, T_2 =** PREB + 1HH (EW), T_3 = 3HH (EW), T_4 = PREB + POEB (EW), T_5 = Weekly weeding (EW), T_6 = WEEDY CHECK (EW),T_7 = 2HH (NS), T_8 = PREB + 1HH (NS), T_9 = 3HH (NS), T_{10} = PREB + POEB (NS),T_{11} = Weekly weeding (NS) ,T_{12} = WEEDY CHECK (NS),

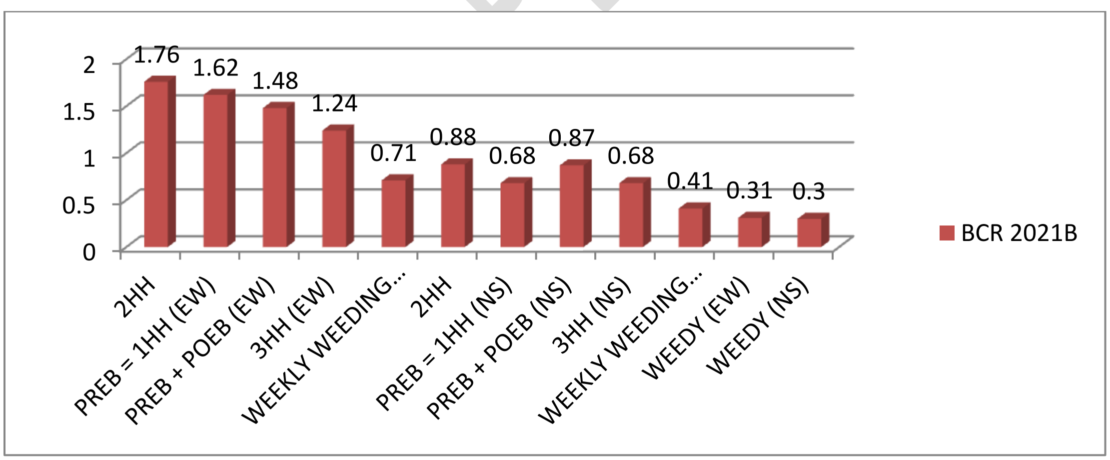

Fig. 1 Benefit Cost Ratios for weeding regimes in EW and NS directions during 2021

The highest BCR of 1.76 (2HH) and 1.62 (PREB + 1HH) in 2021B and 3.3 (HH) and 2.9 (PREB + 1HH) during 2022B denoted the two treatments as the most economical. The treatments PREB + POEB (EW), 3HH recorded and weekly weeding gave low BCR.

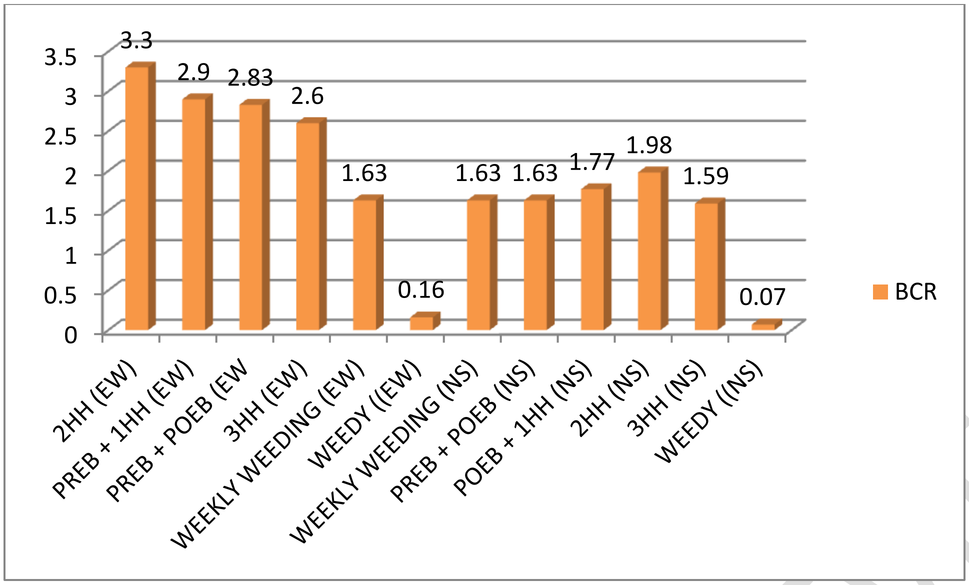

Fig. 2 Benefit Cost Ratios for weeding regimes in EW and NS directions during 2022B

3.5.2 Marginal rate of return from the experiment

A similar trend of results for the yield parameters during 2021B and 2022B was recorded. Marginal rate of return (MRR %) for EW orientation were positive but lower values than zero were recorded due to high costs (D) for the NS orientation (Data not shown) and other EW treatments. (Table 5). 2HH (EW) and PREB + 1HH (EW) produced the highest MRR 0f 714% and 661% respectively.

Table 5 Marginal rate of returns (2022B)

Treatments	Variable costs (Ush)	Net profits (Ush)	Marginal costs (Ush)	Marginal net benefits (Ush)	MRR (%)
Weedy check (EW)	30	686			
2HH (EW)	590	4,686	**560**	**4000**	**714.3**
PREB + POEB (EW)	640	4,014	**50**	**D**	
PREB + 1HH (EW)	715	4,510	**75**	**496**	**661.3**
3HH (EW)	990	3,786	**275**	**D**	
Weekly weeding (EW)	1590	2,586	**600**	**D**	

D = Dominance due to the high cost of production, MRR = Marginal rate of return (%), 1 Us Dollar = 3,500 Ush.

4 DISCUSSIONS

4.1 GROWTH, YIELD PARAMETERS AND YIELD FOR RICE DURING 2021B AND 2022B

Results for the growth and yield parameters in EW and NS row directions had a similar trend during 2021B and 2022B cropping seasons. Higher biometric data collected and yield during

2022B may be attributed to the higher and evenly distributed rainfall during the latter season. Significantly higher growth and yield than rice in EW than NS row directions. Results may be attributed to increased development of the growth and yield attributes in rice a C3 plant. C3 plants established in the EW row direction smother weeds within the inter-rows, eliminate crops competition for light, soil moisture and nutrients and create suitable micro-climate for growth. Generally C3 plants have high rates of photorespiration (22) and have lower numbers of chloroplasts than C4 plants Rising Cabondioxide levels gives comparative advantages to C3 plants through increased photosynthesis, biomass production and yield compared to C4 plants. C4 plants benefit from rising global temperatures than C3 plants (22). EW row direction thus, eliminates crops' light competition and creates suitable micro-climate for enhanced physiological processes and growth of rice. Results are supported by (7) and (17). 2HH, + 1 HH, PREB + POEB and 3HH in the EW direction produced higher growth attributes, yield attributes and grain yield than other treatments. This may be attributed to more effective control of the weeds at the critical period (CP) of weed control under the treatments. CP for upland rice is on average 15 - 45 days after seed germination (DAG) and this coincided with the period when hand hoeing (14, 28 & 42 days after seed emergency (DAE) and time of application of both the pre (planting) and post emergence (28 DAE) herbicides were applied. (19). (20), reported the critical period for NERICA rice to be 14-42 days after sowing. (26), observed chemical weed control to increase the growth and yield of associated rice crop.
Weed free conditions up to 42 DAE of rice in the EW row direction reduced the yield parameters and rice grain yield relative to the other treatments in EW row orientation. Reduction in yield attributes and yield is associated with the high exposure of the root zone and plant roots to high temperatures, increased moisture and nutrients loss through erosion leaching and evaporation, Rice being a C3 plant is adapted to cool conditions. Similar number of leaves and plant height under the weekly weeding and all EW row treatments may be associated with possible equivalent interception of solar radiation and nutrient and water uptake by rice coupled with reduced competition with weeds under conditions of low weed density for rice under the 3 different treatments. EW orientation could have had similar above ground conditions for the CP (15 - 45 DAG) of weed control. Lower number of leaves, tillers, panicles per rice plant and grain yield per hectare for rice the NS row direction than rice in the EW row orientation under all treatments may be attributed to possible low interception of solar radiation during the CP of weed control and reduced uptake of soil moisture and nutrients that may be associated with inter-species competition between rice and increased weed densities in the NS row directions. Weekly weeding in NS direction gave high leaves, panicles per plant and numerically high rice grain yield. Results may be attributed to effective interception of solar radiation soil moisture and nutrients during the critical period of weed control under this treatment. (15), reported weed control to significantly influence plant height, tiller number, crop growth rate, yield attributes and yield of rice. Weedy checks produced low numbers of leaves, tillers, panicles and rice grain yield amongst all treatments. This may be linked to reduced physiological processes that influence crop growth, development and yields of the rice crop due to competition with weeds for space, nutrients, air, water and light. Reduced yield losses of 74% and 80% were reported by (4, 6) in rice. (7), reported 100% yield loss due to weed infestation in rice. Higher grass biomass under the weedy check in the EW than NS direction may be attributed to the higher biomass development due to higher interception of solar radiation by weeds between rice rows in the EW than SW row direction. Physiological processes that would enhance rice crop growth were hindered by the high weed density irrespective of the rice row direction.

4.2 YIELD PARAMETERS AND YIELD OF RICE DURING 2022B

Rice in EW row direction produced significantly high panicles per plant, longer panicles and rice grain yield. Results may be accredited to increased development of the growth, yield attributes and yield of rice which is a C3 plant. When C_3 plants are planted in the EW row direction, they smother weeds within the inter-rows resulting into reduced competition between rice and weeds for nutrients and air. Results are supported by (17) who reported that crops EW orientation reduces light competition and creates suitable micro-climate for obtaining the maximum rice grain yield through solar radiation interception and increased photosynthesis. This condition could have led to enhanced crop physiological processes like water and nutrient uptake, solar radiation absorption and increased deposition of assimilates in the yield components and high grain yield. Increased crop growth by C3 in EW row direction was similarly observed by (7). (16) similarly observed that improper rice row orientation affects crop growth and yields. 2HH, PREB + 1 HH and weekly weeding (EW) recorded higher yield parameters and grain yield than other treatments. This is associated with effective control of the weeds done at the critical period (CP) of weed control (15-45DAG) under the treatments. The 3 treatments exhibited weed free conditions during the CP that enhanced development of yield attributes and grain yield. (19, 20) emphasized the significance of weed control during the CP in order to maximize rice yields. Grains per panicles, length of grains, and grain yield under weekly weeding was low. High exposure of the root zone and plant roots to high temperatures, increased loss of moisture and nutrients from the soil may have caused the result. On the contrary, (16) observed highest rice grain yield (6.71t ha^{-1}) under weed free conditions. PREB + POEB treatment in the NS row direction similarly produced short rice panicles which may be attributed to reduced nutrient uptake from the soil under conditions of highly exposed soil conditions under the treatment. Lower number of leaves, plant height, number of tillers and shorter leaves under the weedy checks than all other treatments relates to possible reduction in the physiological process that promote crop growth. Weeds have been reported to reduce rice crop growth yield attributes and yield (5, 6, 7). EW control treatment produced 10 Mt Ha^{-1} compared to a lower weight of 7.5 Mt Ha^{-1} of weeds in the NS row direction. This could have resulted from the higher absorption of incident radiation, ambient soil conditions and reserve moisture in EW orientation. Such conditions could have favored higher weed seed germination and development than under NS direction. The latter was reported by (5) who noted that crops in EW are more competitive than in NS orientation.

4.3 ECONOMICS OF WEED MANAGEMENT OPTIONS

4.3.1 Production costs and income

2HH and PREB + 1HH (EW) produced high net income due to the high gross returns arising from high rice grain yields and low net costs of production in 2021B and 2022B. Low net gross income from 3HH and PREB + POEB and weekly weeding (EW), despite relatively high grain yield was due to high variable production costs. Highest variable costs were under weekly weeding due to high variable labor costs.

4.3.2 Benefit cost ratio

Maximum BCR that were observed under 2HH and PREB + 1HH in the EW row direction during 2021B and 2022B originated from the high rice grain yield and accrued net income with relatively low production costs. Low BCR under PREB + POEB (EW) and 3HH were due to high production labor costs.

4.3.3 Marginal rate of return

High and positive marginal rate of return (MRR %) for EW orientation during 2022B signified the superiority of EW over NS direction in economic benefits from rice production. The high MRR % under 2HH (EW) and PREB + 1HH (EW) during 2022B indicated that the 2 treatments were the most economical for any additional investment of added costs. Similar observations were made for 2HH and pre application of Atrazine herbicide (2 L/ha) in maize by Kaiira *et al*, (2014).

5. CONCLUSION

Mean numbers of leaves, plant height, number of tillers leaf length and total panicles per plant, panicle length, grains panicle^{-1} and yield were significant during 2021B and 2022B. EW orientation produced higher observations than NS row directions. 2HH, PREB +1 HH, PREB + POEB and 3HH in the EW direction produced higher mean numbers of leaves, plant height, number of tillers, total panicles per plant and higher rice grain yield than other treatments during the 2 years. 2HH and PREB + 1HH (EW) recorded high benefit cost ration (BCR) and marginal rates of returns (MRR %). PREB + POEB and 3HH in EW direction produced lower number of leaves and tillers and grain yield during 2022B with low BCR and MRR (%). Plant height and leaf length both EW and NS row directions during 2022B were at par except under the weedy checks that recorded lower observations. Weekly weeding up to 42 DAE in the EW row direction reduced the tillers, panicles and rice grain yield in EW row orientation but recorded similar number of leaves and plant height to the other treatments in the same direction. High numbers of panicles per plant and numerically higher rice grain yield (NS) was recorded during 2021B with high number of leaves, and tillers per plant and numerically high plant height and leaf length during 2022B. Weedy checks produced low numbers of leaves, tillers, panicles and rice grain yield amongst all treatments during 2021B and 2022B. Field observations during 2021B and data during 2022B indicated higher grass biomass in the EW than NS direction. Change of row directions did not influence the growth and yield of rice under the weedy treatments during both seasons. Based on the results 2HH and PREB + 1HH in the EW row direction gave maximum BCR and MRR and the options are recommended in upland rice ecosystems.

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