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Assessing Herbicide Use and Hand Weeding Efficacy in Groundnut Production Intensification

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Abstract

Poor and costly weed management constrains Groundnut (*Arachis hypogea* L.) production in Uganda. A field study was therefore conducted at the National Semi-Arid Resources Research Institute (NaSARRI), Serere, Uganda during the long rains of 2020 and 2021 and short rains of 2020 to evaluate the efficacy of hand weeding and different herbicides on weed management, yield, and the economics of their use in groundnut. The experiment for this study comprised 7 treatments constituted by six herbicides; four pre-emergent (Glyphosate, Clethodim, S-Metolachlar, and 2,4-Dichlorophenoxyacetic acid), and two post-emergent (Bentazone and Quizalofop-p-ethyl) and hand weeding. Post-emergence herbicide application and hand weeding were done at 30, 45, and 60 DAS. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Calculated weed indices show the effect of weed control measures on groundnut weeds. Pre-emergence application of glyphosate followed by post-emergence application of Quizalofop-p-ethyl produced superior pod yield (1724.3 kg/ha), the lowest weed density of grass (0.62), and Sedges (0.61), the lowest weed biomass at harvest (122.5g), the highest percentage of weed control efficiency (69.65%), and highest net returns (7,937,746UGX/ha). However, post-emergence sole application of quizalofop-p-ethyl produced the highest B: C ratio (36.49). Therefore, this study has indicated that the pre-emergence application of glyphosate followed by the post-emergence application of quizalofop-p-ethyl is the most profitable weed control measure in groundnut; while the post-emergence sole application of quizalofop-p-ethyl is the most economical. Hand weeding though may be used where labour is cheap and not scarce as opposed to the herbicides.

Keywords: weed indices, weed control efficiency, groundnut production intensification, weed biomass

1. Introduction

Groundnut (*Arachis hypogaea*) forms an integral part of the cropping system of the Northern and Northeastern regions of Uganda due to its good adaptability to dry conditions and food systems. This crop is very versatile with multiple advantages to the farmers; as an alternative source of protein, income, and food security (Okello et al., 2010). It can enhance soil fertility through nitrogen fixation. Much of groundnut is grown by small-scale farming households particularly women operating at the margins of subsistence (Christie et al., 2015). Most of these farmers have no access to inputs such as; improved seeds, fertilizers, pesticides, and improved implements. In the two regions above, on-farm groundnut yields are extremely low averaging less than 1 ton/ha compared to potential yields of 3 tons/ha (Kaizzi et al., 2012). Groundnut crop yields depend on various agronomic management practices and between (74 to 92%) of crop loss can be realized in a poorly weed-managed field (Agostinho et al., 2006).

Weeds reduce yields by competing with the groundnut plant for resources (sunlight, space, moisture, and nutrients throughout the growing season (Upadhyay, 1984). Worse still, they create a problem during digging and inverting procedures consequently reducing a groundnut crop harvesting efficiency. The critical period of crop-weed competition for a groundnut crop occurs up to 45 days after sowing (Prasad et al., 1987). Compared to other crops, weeds also interfere with pegging, pod development, and harvesting of groundnuts. For groundnuts lifted and allowed to dry in the field, harvesting losses increase due to the biomass of weeds slowing down the drying of groundnut vines and pods and increasing the possibility of exposure to rain. Besides weeds have allelopathic effects on groundnut and act as a host for several groundnut diseases and pests (Bansal, 1993).

The critical period of grass weed control is between 4 to 9 weeks after planting, while the critical period for broadleaved control is between 2 to 8 weeks after planting (Wesley et al., 2008). Groundnut yields tend to decrease with increasing time of weed interference with all types of weed species (Zimdhal, 2013). This, therefore, calls for timely control of weeds. Most small-scale farmers use rudimentary implements like hand hoes to manage weeds. However, hand weeding is time-consuming, less timely, and is associated with drudgery (Walia et al., 2007). Herbicide use is likely groundnut's most effective and economical weed management method. However, its efficiency and cost-effectiveness in weed control have not been explored well in Eastern and Northern Uganda. This investigation was therefore conducted to identify an effective and economically viable herbicide in weed control on groundnut in the above two regions of Uganda.

2.0 Materials and Methods

2.1 Experimental Site

This study was conducted at the National Semi-Arid Resources Research Institute (NaSARRI-Serere), Uganda during the long rains of the 2020 planting season (from March to July), the short rains of the 2020 planting season (from September to November) and long rains of 2021 planting season (from March to July) to determine the most effective and economical herbicide in managing weeds in groundnut as compared to hand weeding. NaSARRI is at $0^{o}32'$N and $35^{o}27'$E at 1128 meters above sea level.

2.1.1 Weather and Soil Conditions at the Experimental Site

The site experiences a bi-modal rainfall pattern with an average minimum temperature of 17.9 ^{o}C and a maximum temperature of 29.4 ^{o}C. The relative humidity ranges from 72 to 84% annual temperatures. The soils at the experimental site are mainly sandy with low organic matter and are classified as Petric Plinthosols with observed traces of soils classified as gleysols and vertisols (Aniku, 2001).

2.2 Treatments and Experimental Design

The treatments comprised of; Select 120 EC (Clethodim), S-Metolachlar, and 2,4 D (2,4-Dichlorophenoxyacetic acid) were applied at pre-planting while combined application of; Clethodim + Quizalofop-p-ethyl and Glyphosate + Quizalofop-p-ethyl is done at pre-planting and post-planting at 30, 45 and 60 DAS. For the sole application of Bentazone and Quizalofop-p-ethyl and, hand weeding, it was done post-planting at 30, 45, and 60 DAS. These were replicated thrice in a randomized complete block design (RCBD). Serenut 5R was the groundnut variety used for this experiment. It is in the Virginia class of groundnuts with semi-erect growth habits. It was chosen because it falls between bunch and spreading types of groundnuts.

2.2.1 Mode of Action of the Herbicides

2,4 Dichlorophenoxyacetic acid kills broadleaved weeds by mimicking auxin thus causing uncontrolled and disorganized plant growth leading to plant death. Glyphosate kills weeds by inhibiting enzyme (EPSP) synthase responsible for the manufacture of aromatic amino acids like tryptophan; while quizalofop-p-ethyl is hydrolyzed to quizalofop-p that becomes an inhibitor of fatty acid synthesis through CoA carboxylase enzyme.

2.3 Crop Husbandry

Seeds of groundnuts were sown at 45 cm between rows and 10-15 cm between plants. Weeds were controlled by hand weeding and herbicide application. Hand weeding was done at intervals of 30, 45, and 60 DAS, while herbicides were applied pre-emergence and post-emergence. Post-emergence herbicides were applied at intervals of 30, 45, and 60 DAS. Hand weeding was used as a common method used by farmers in managing weeds in groundnut and it acted as a reference or control.

2.4 Data Collection

The data presented was recorded in three seasons of experimentation; long rains of 2020 planting season, short rains of 2020 planting season and long rains of 2021 planting season.

2.4.1 Weed Parameters

(1) Changes in Weed Flora

To account for changes in weed flora under different treatments, different weeds under three classes (sedges, grasses, and broadleaved) were recorded at intervals of 14 days up to groundnut harvest.

(2) Weed Density

Denotes a number of weeds (broad-leaved, grasses and sedges) per unit area. It is achieved by counting the number of weeds in the experimental plot and dividing by the size of the plot or area of the plot. Expressed as N/m^2

(3) Weed Biomass

Indicates biomass of weeds per unit area. It is achieved by harvesting weeds from the experimental plot, and then drying and weighing them. The resultant biomass is then divided by the area of the experimental plot and it is expressed as g/m^2 or kg/acre or ha

(4) Weed Control Efficiency (WCE)

Represents a magnitude of weed reduction due to weed management treatments. Its value was determined using the formula derived by Mani et al in 1973 and expressed in percentage as follows,

$$\text{WCE\%} = \frac{\text{Dry matter of weeds in an un-weeded plot - Dry matter of weeds in a treated plot}}{\text{Dry matter of weeds in the un-weeded plot}} \times 100 \quad (1)$$

(5) Weed Index (WI)

Denotes a measure of the efficiency of a particular treatment compared with a weed-free treatment. It is expressed as a yield potential under weed-free. It represents yield loss caused by weeds compared to unweeded ones. It is expressed as follows,

$$\text{WI\%} = \frac{\text{Yield of weed-free plot - Yield of the treated plot}}{\text{Yield of a weed-free plot}} \quad (2)$$

(6) Agronomic Management Index (AMI)

$$\text{AMI} = \{[(Y_t - Y_c)/Y_c] - [(W_c - W_t)/W_c]\}/\{[W_c - W_t]/W_c\} \quad (3)$$

where, Y_t = Yield of treated plot; Y_c = Yield of control (Unweeded) plot; W_c = Weed weight in a control (Unweeded) plot; W_t = Weed weight in a treated plot.

Higher AMI denotes lower WCE, and relatedly lower addition of yield occurs with treatment.

2.5 Growth and Yield Parameters and Yield

2.5.1 Growth Parameters

Ten plants were selected from each plot and tagged, on which observations were made on plant height. This was done by measuring the height of the plant using a meter ruler.

2.5.2 Yield Parameters and Yield

The groundnut crop was harvested at maturity and the number of pods/plant and yield per plot (kg/ha) were determined.

2.6 Economic Returns of Herbicide Use

Gross returns or total benefits per treatment were determined by the sale of total pod yield at the prevailing market prices. The net returns per treatment were calculated by subtracting total costs from total sales or total benefits or gross returns of total pod yield. Gross returns were also used to calculate the Benefit Cost (B:C) ratio by dividing total benefits by total costs.

2.7 Data Analysis

Data recorded on weed response parameters to different management methods and yield and yield parameters of groundnuts were subjected to analysis of variance (ANOVA) using Genstat statistical package; where the ANOVA gave significant F values, means were compared using the least significant difference (LSD) test at $P \leq 0.05$. Data for weed densities was transformed using square root.

3. Results

3.1 Weed Status Before and After Experimentation at the Experimental Plots

3.1.1 Weed Flora and Density Before Experimentation on the Experimental Plots

The dominant broad-leaved weeds at the experimental plots were; *Mitracarpus hirtus* (Tropical girdle pod), *Senna obustusfolia* (Sickle pod), *Leucas martinicensis* (White wort), *Acanthospermum hispidum* (goats head), *Celosia leptostachya* (Red spinach), *Corchorus triden* (Horn fruited jute) and *Oxalis latifolia* (Sorrel); while the dominant grass weeds were; *Panicum maximum* (guinea grass), *Cynadon dactylon* (Bermuda grass), *Digitaria eriantha* (Digit grass). The common sedge weeds at the experimental plots were; *Cyperus rotundus* (Nutsedge) and *Cyperus difformis* (Umbrella sedge). The total weed count of broadleaved and grass weeds per plot was 15 and 10, respectively, before experimentation.

3.1.2 Weed Density as Influenced by Different Weed Control Methods

(1) Weed Density as Influenced by Different Weed Control Methods at 45 DAS

At 45 DAS different weed control treatments did not significantly ($P < 0.05$) affect the weed density of two weed classes; broadleaved (BL) and grass (GR); but in contrast, all weed control treatments had significantly ($P < 0.05$) higher Sedges (SG) weed density than unweeded treatment during the same period (Figures 1, 2 and 3). Although the application of different weed control treatments did not significantly ($P < 0.05$) affect GR and BL weeds in groundnut, results in Figures 1, 2 and 3 show that plots treated with glyphosate combined with quizalofop-p-ethyl had the highest average BL weed density (7.33); while plots treated with 2,4 D had the highest average GR weed density of 4.3 (Figures 1, 2 and 3).

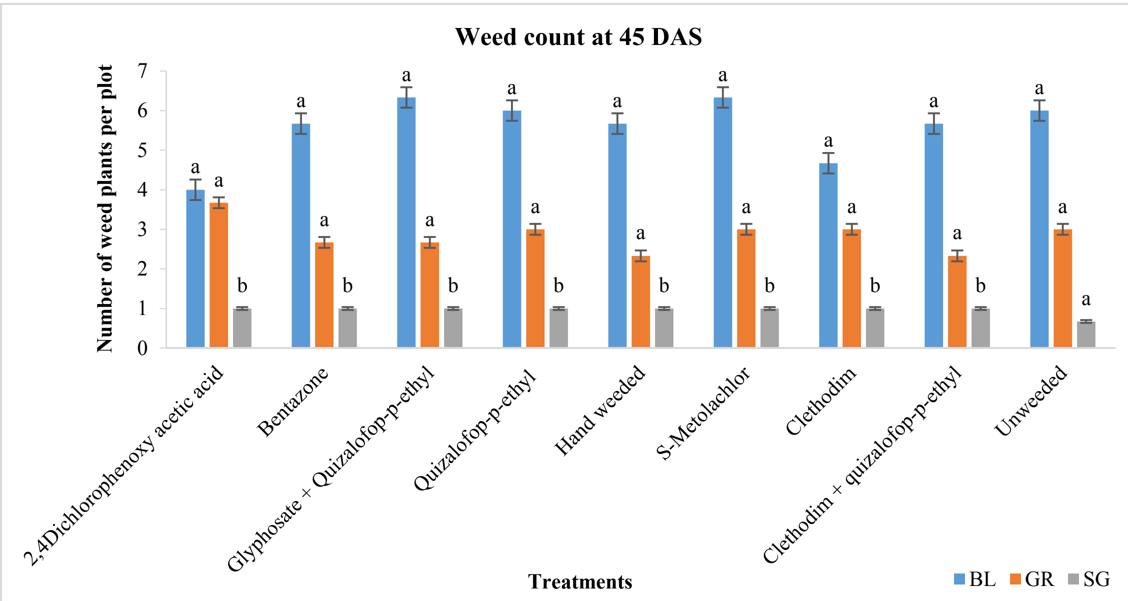

Figure 1. Showing the effect of weed control methods on weed density in groundnuts at 45 DAS during the long rains of 2020

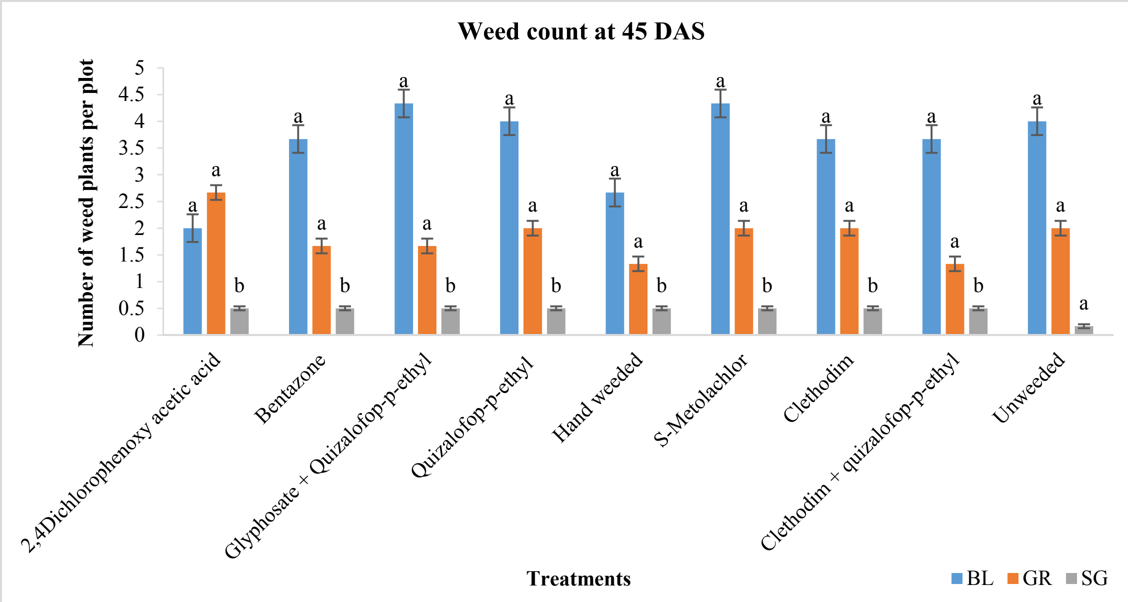

Figure 2. Showing the effect of weed control methods on weed density in groundnuts at 45 DAS during the short rains of 2020

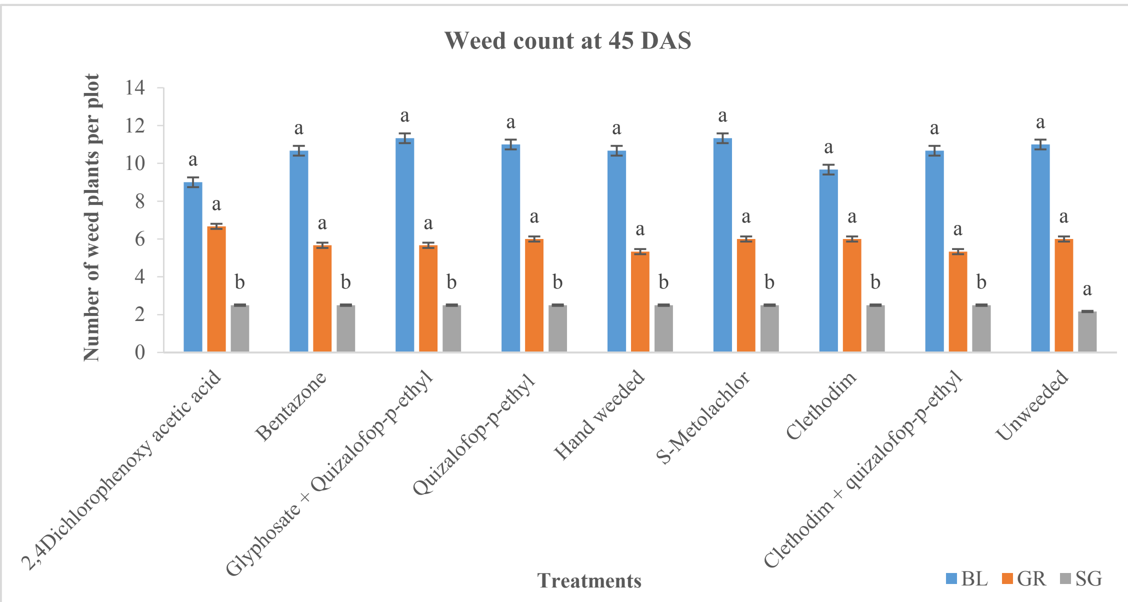

Figure 3. Showing the effect of weed control methods on weed density in groundnuts at 45 DAS during the long rains of 2021

(2) Weed Density as Influenced by Different Weed Control Methods at 60 DAS

Results in Figures 4, 5 and 6 indicate that application of different weed treatments on groundnuts at 60 DAS significantly ($P < 0.05$) affected the weed density of all the weed classes (BL, GR, and SG). The data in Figures 4, 5 and 6 also revealed that plots treated with 2,4 D (sole) had significantly ($P < 0.05$) the highest average weed density of GR (2.56) compared to other weed control treatments except for unweeded plots which had a GR average weed density of 3.45; while plots treated with glyphosate combined with quizalofop-p-ethyl had the highest average weed density of BL (4.72).

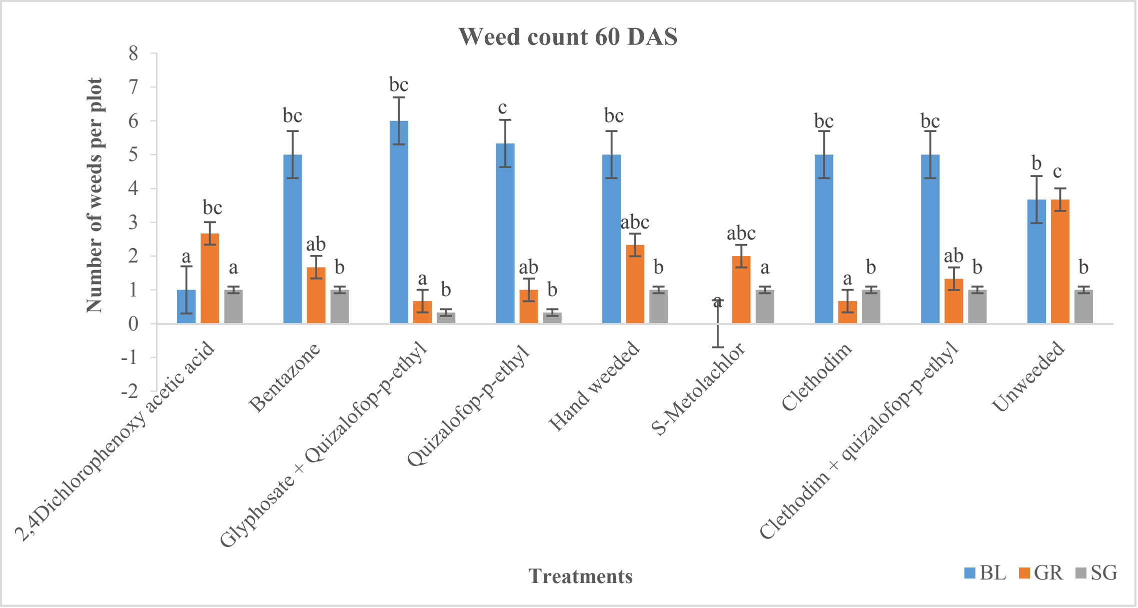

Figure 4. Showing the effect of weed control methods on weed density in groundnut at 60 DAS during the long rains of 2020

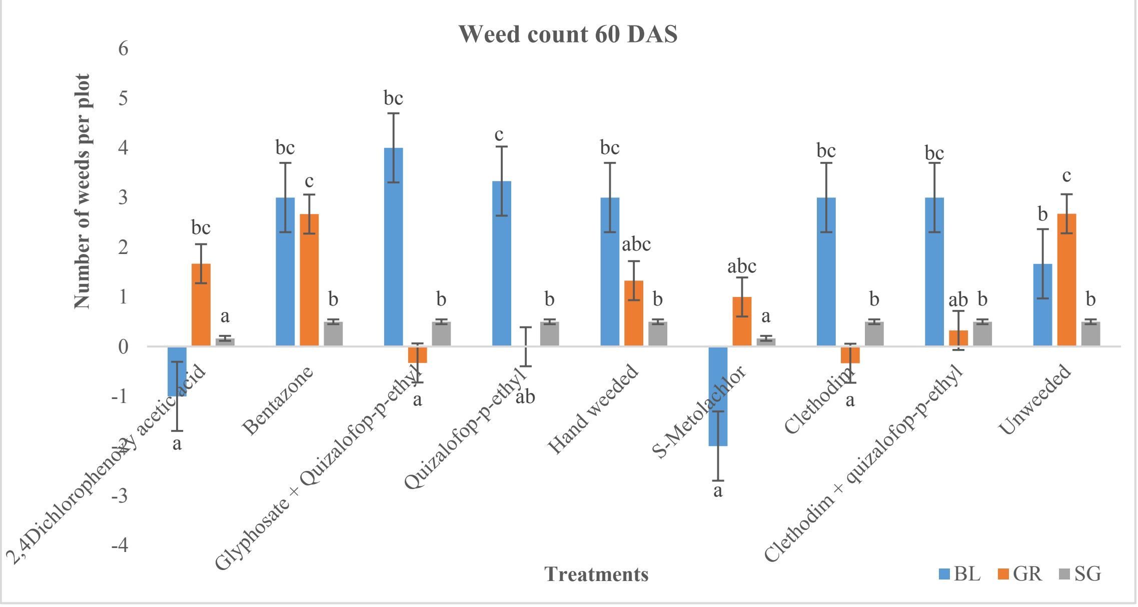

Figure 5. Showing the effect of weed control methods on weed density in groundnut at 60 DAS during the short rains of 2020

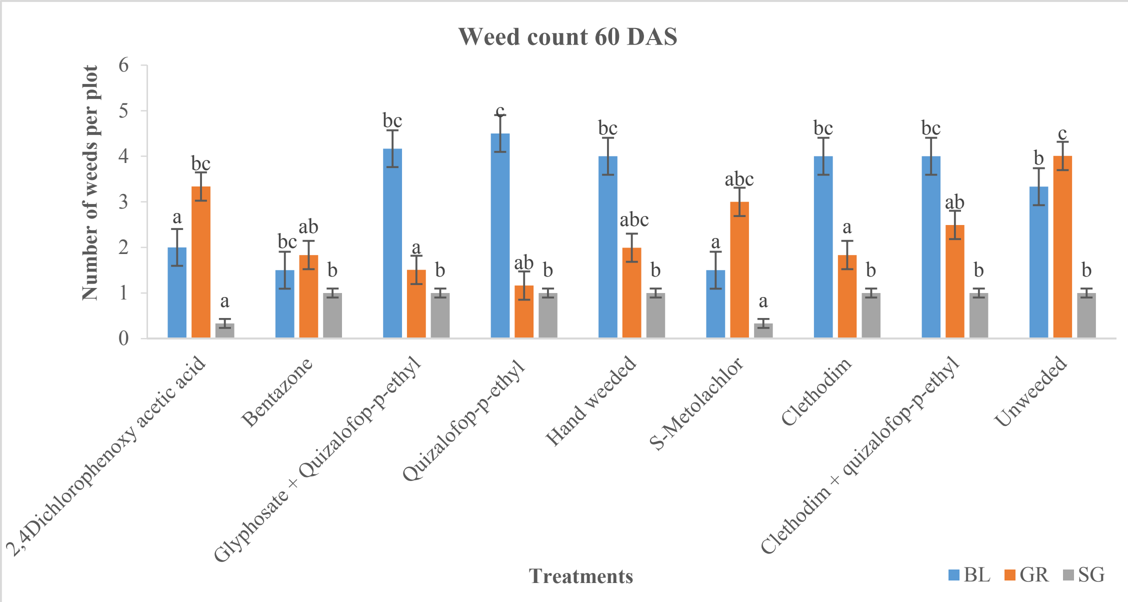

Figure 6. Showing the effect of weed control methods on weed density in groundnut at 60 DAS during the long rains of 2021

3.2 Weed Biomass as Influenced by the Different Weed Control Methods

Results in Figures 7, 8 and 9 revealed that biomass of broadleaved weeds (BL) and grasses (GR) at both 45 and 60 DAS was not significantly ($P < 0.05$) affected by different weed control methods; while at harvest their weed biomass was significantly ($P < 0.05$) influenced by different weed control methods. Hand weeding had significantly ($P < 0.05$) the highest average reduction of weed biomass at harvest by 81.5% followed by plots treated with glyphosate combined with Quizalofop-p-ethyl (76.3%). On the contrary, the results in Figures 7, 8 and 9 revealed that among herbicide treatments, 2,4D sole had significantly ($P < 0.05$) higher weed biomass compared to other treatments.

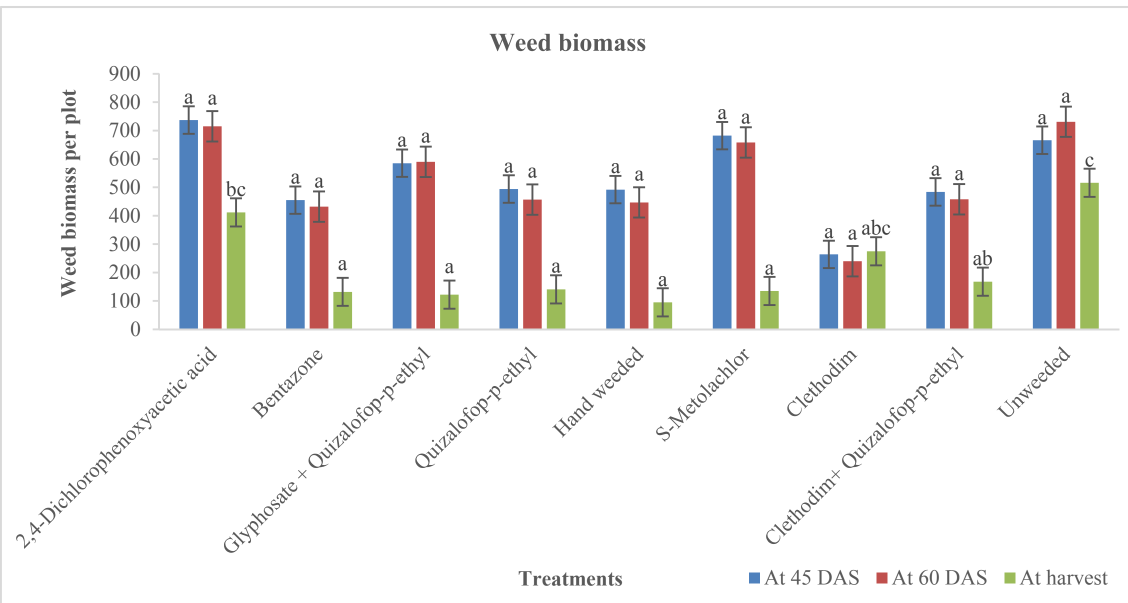

Figure 7. Showing the effect of weed control methods on weed biomass in groundnut at 45 DAS, 60 DAS, and harvest during the long rains of 2020

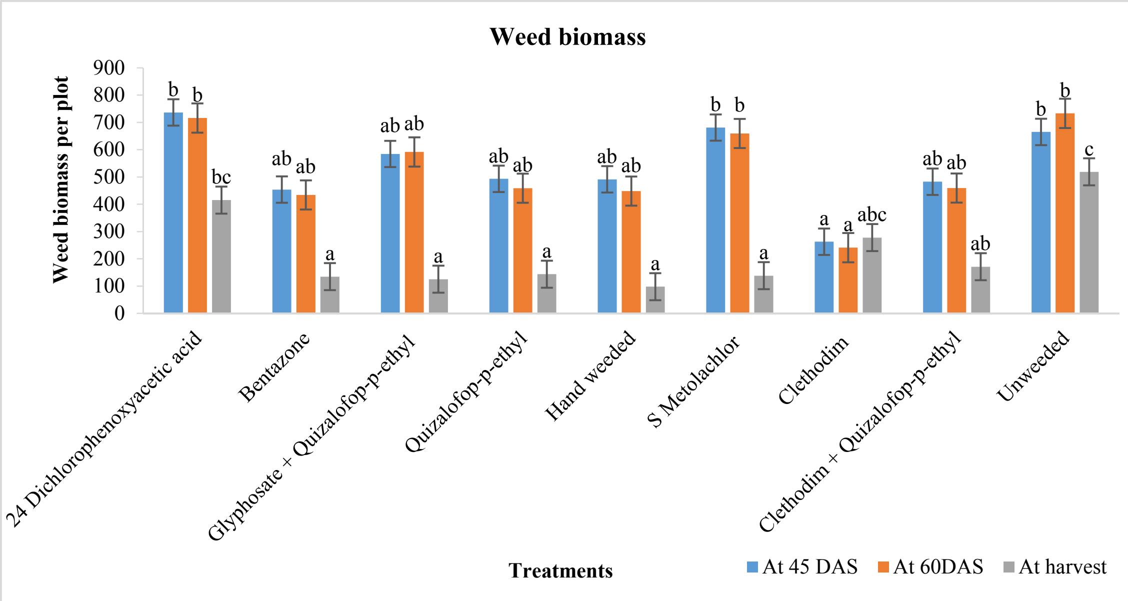

Figure 8. Showing the effect of weed control methods on weed biomass in groundnut at 45 DAS, 60 DAS, and harvest during the short rains of 2020

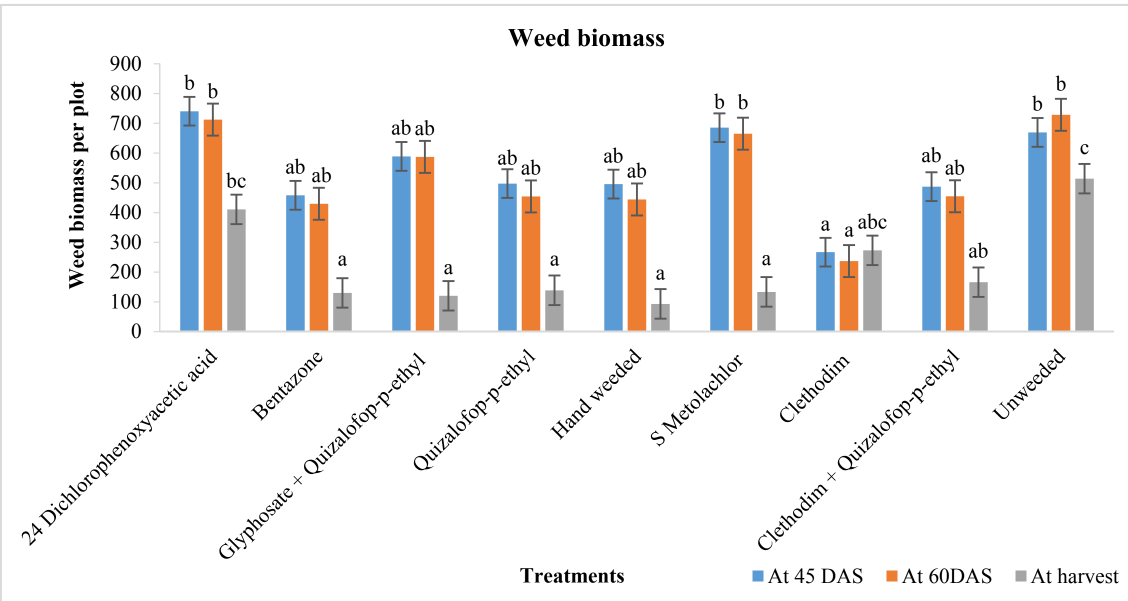

Figure 9. Showing the effect of weed control methods on weed biomass in groundnut at 45 DAS, 60 DAS, and harvest during the long rains of 2021

3.3 Weed Index (WI) as Influenced by Different Weed Management Practices in Groundnut

Conspicuous changes were observed in the weed index under different weed management practices in groundnut (Figures 10, 11 and 12). The average weed index was significantly ($P < 0.05$) lowest under combined application of glyphosate and quizalofop-p-ethyl (5.5%) followed by sole application of quizalofop-p-ethyl (10.16%), and then hand weeding (11%) (Figures 10, 11 and 12). In contrast, plots treated with 2,4D, Clethodim, and those that weren't weeded at all had significantly ($P < 0.05$) higher average weed indices; 68.4%, 62.3%, and 73.9%, respectively (Figures 10, 11 and 12).

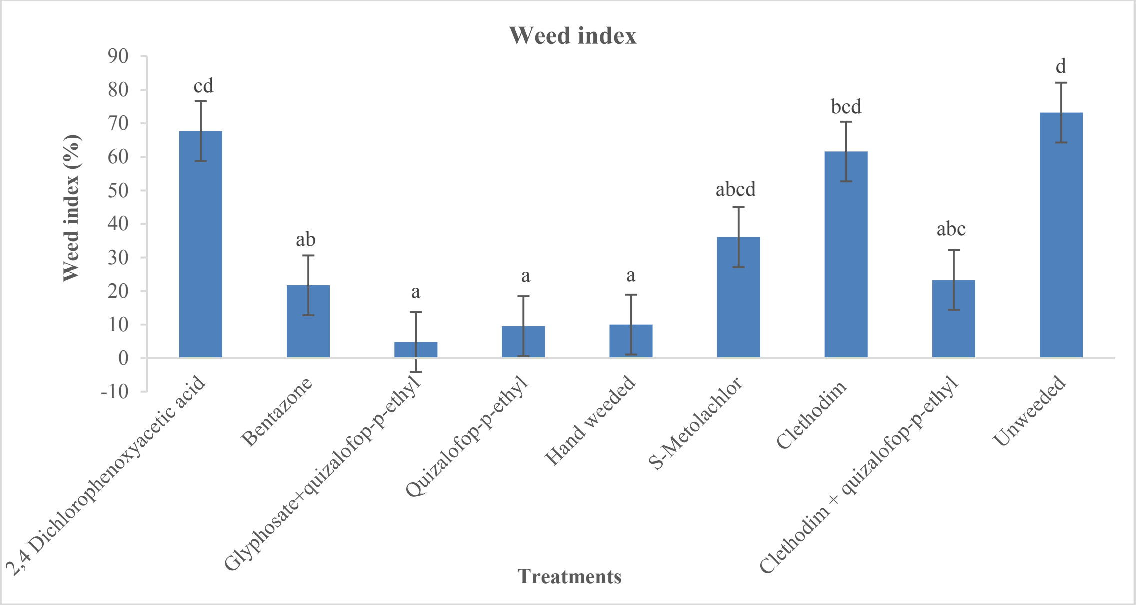

Figure 10. Showing the effect of different weed management practices on the weed index in groundnut during the long rains of 2020

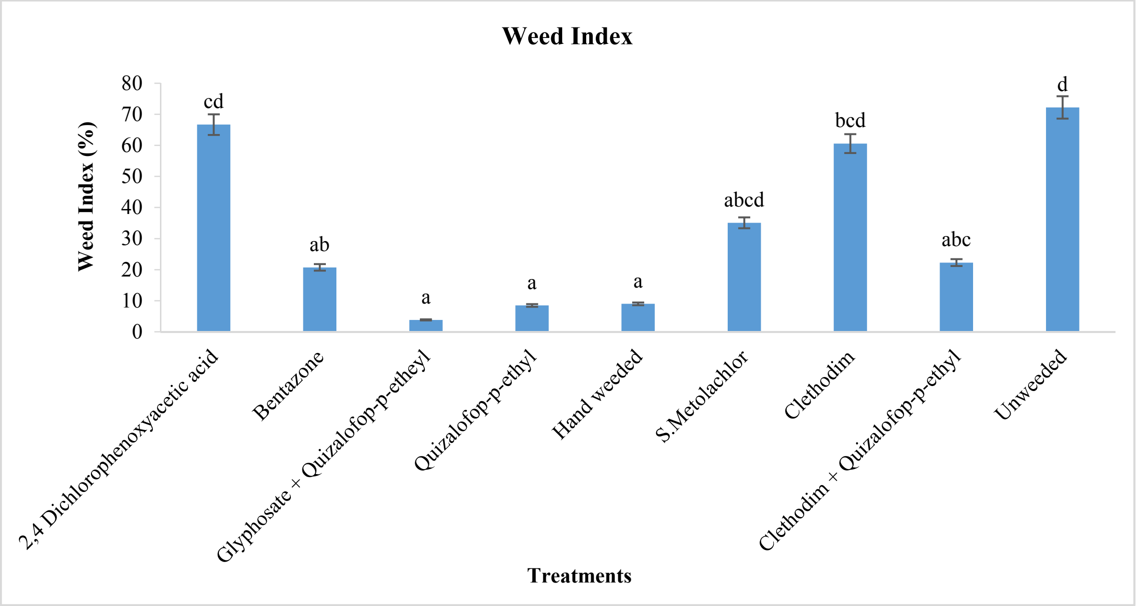

Figure 11. Showing the effect of different weed management practices on the weed index in groundnut during the short rains of 2020

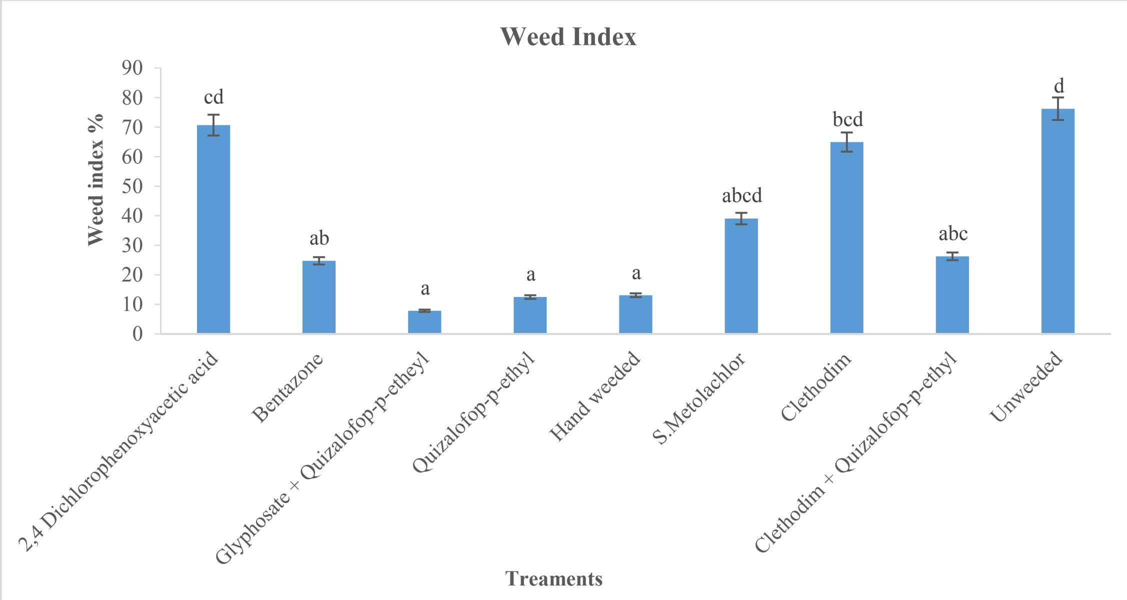

Figure 12. Showing the effect of different weed management practices on the weed index in groundnut during the long rains of 2021

3.4 Weed Control Efficiency (WCE) as Influenced by Different Weed Management Practices

Weed control efficiency was significantly ($P < 0.05$) affected by different weed management practices (Figures 13, 14 and 15). The significantly ($P < 0.05$) highest average WCE (69.7%) was recorded in hand-weeded plots, followed by plots treated with glyphosate combined with quizalofop-p-ethyl (69.6%) and then by quizalofop-p-ethyl applied alone (55.1%) (Figures 13, 14 and 15). In comparison, statistically the lowest average WCE (-13.0%) was observed in un-weeded plots followed by plots treated with 2,4 Dichlorophenoxyacetic acid alone (4.1%) and then clethodim (7.7%) also applied sole (Figure 13, 14 and 15).

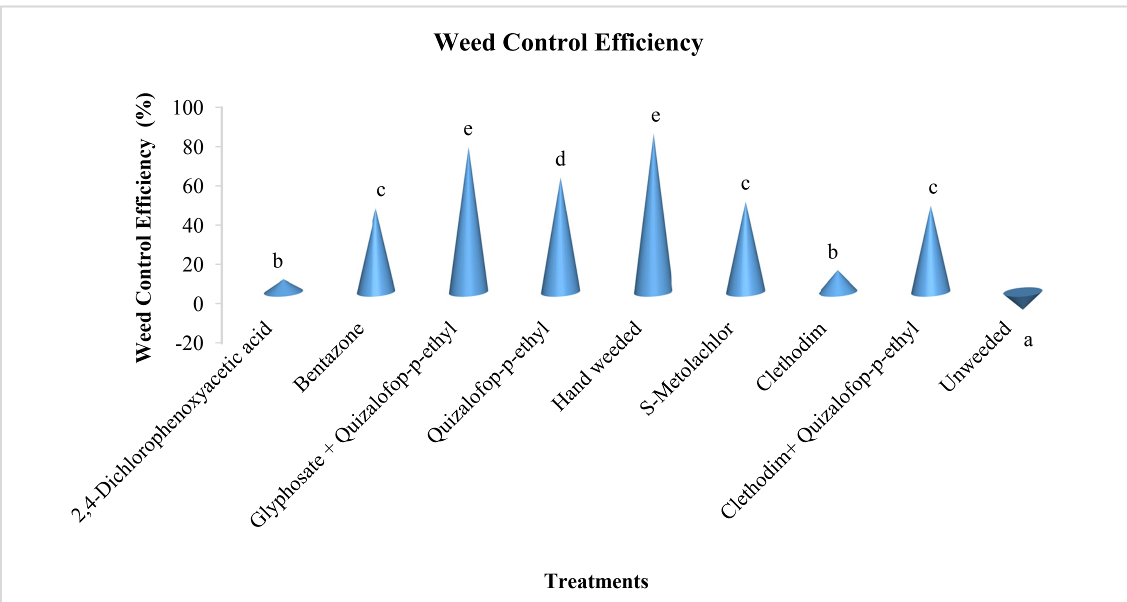

Figure 13. Showing Weed Control Efficiency as influenced by weed management practices in groundnut during the long rains of 2020

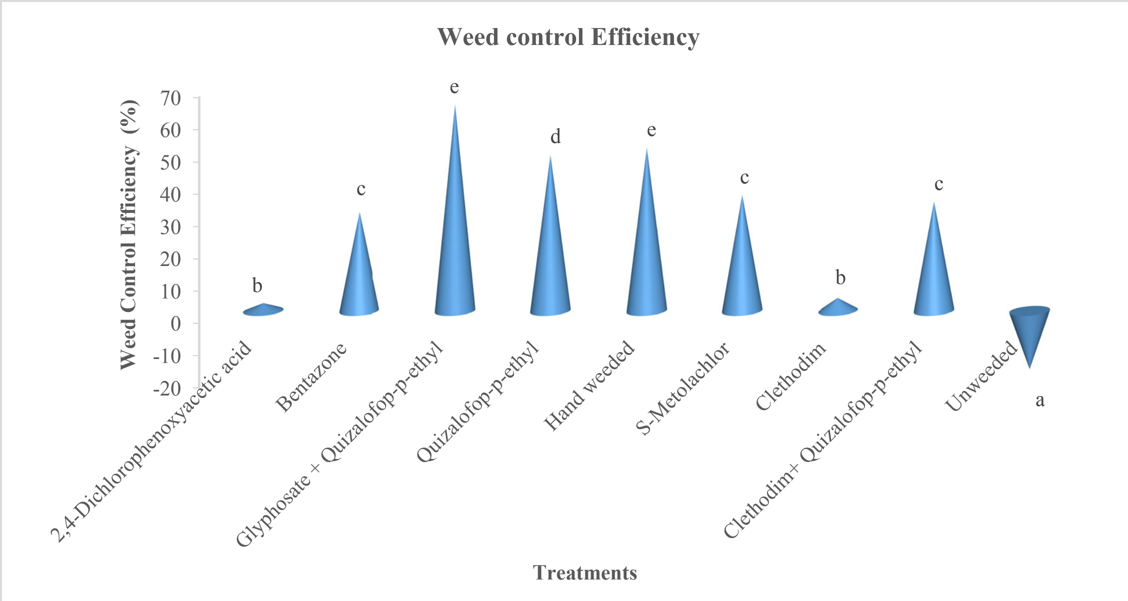

Figure 14. Showing Weed Control Efficiency as influenced by weed management practices in groundnut during the short rains of 2020

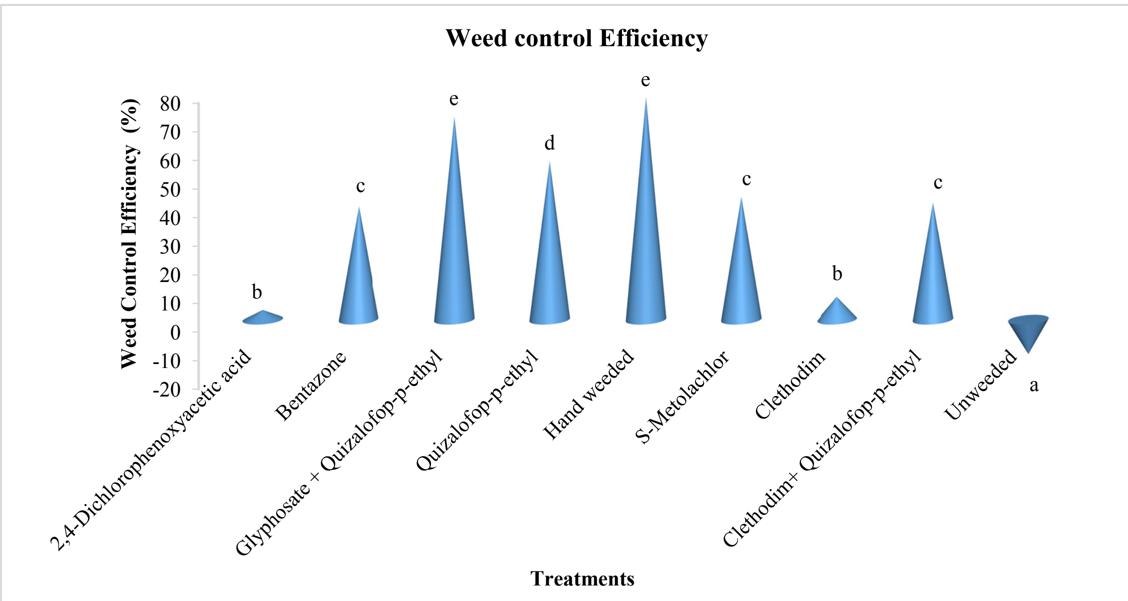

Figure 15. Showing Weed Control Efficiency as Influenced by Weed Management Practices in groundnut during the long rains of 2021

3.5 Agronomic Management Efficiency (AME) as Affected by Different Weed Control Methods On Groundnuts

Results in Figures 16, 17 & 18 revealed that the agronomic management index (AMI) was significantly ($P<0.05$) affected by different weed control methods. A significantly higher average AMI (15.01) was observed in plots treated with Glyphosate combined with Quizalofop-p-ethyl compared to other treatments and the control (Table 1). Results in Figures 16, 17 & 18 also show that the significantly lowest average of AMI (0.86) was observed in plots treated with 2,4 D.

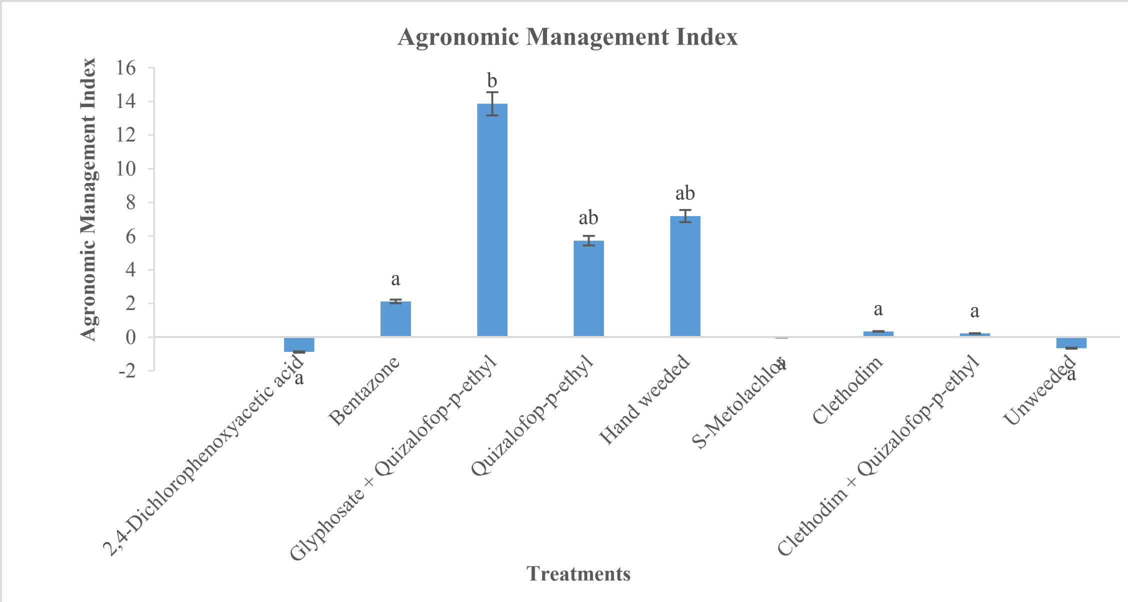

Figure 16. Showing the Agronomic Management Index of the weed control methods in groundnut during the long rains of 2020

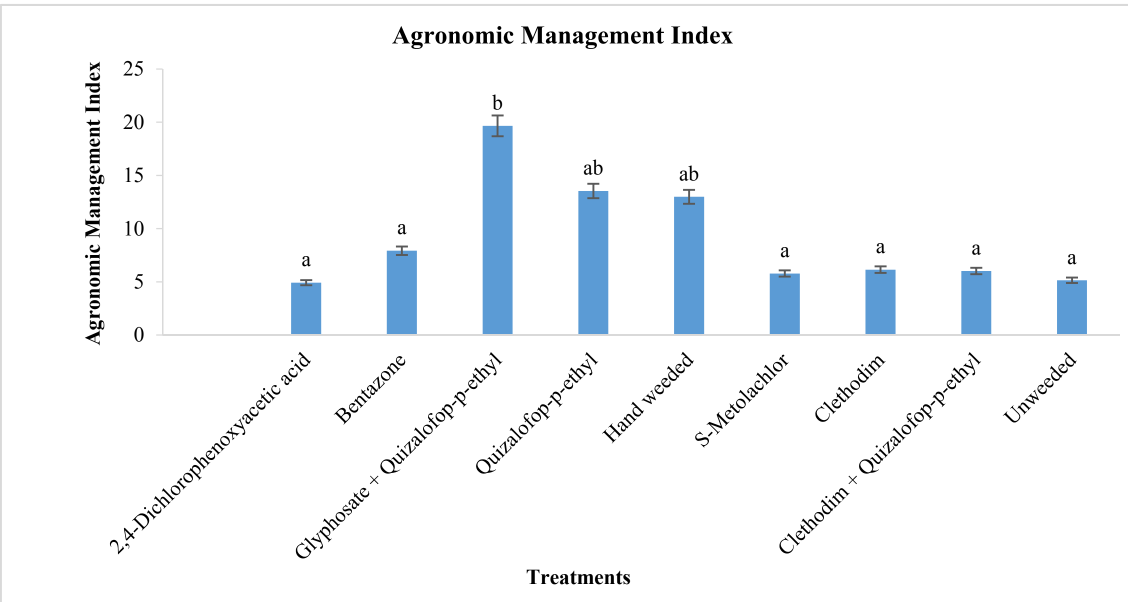

Figure 17. Showing the Agronomic Management Index of the weed control methods in groundnut during the short rains of 2020

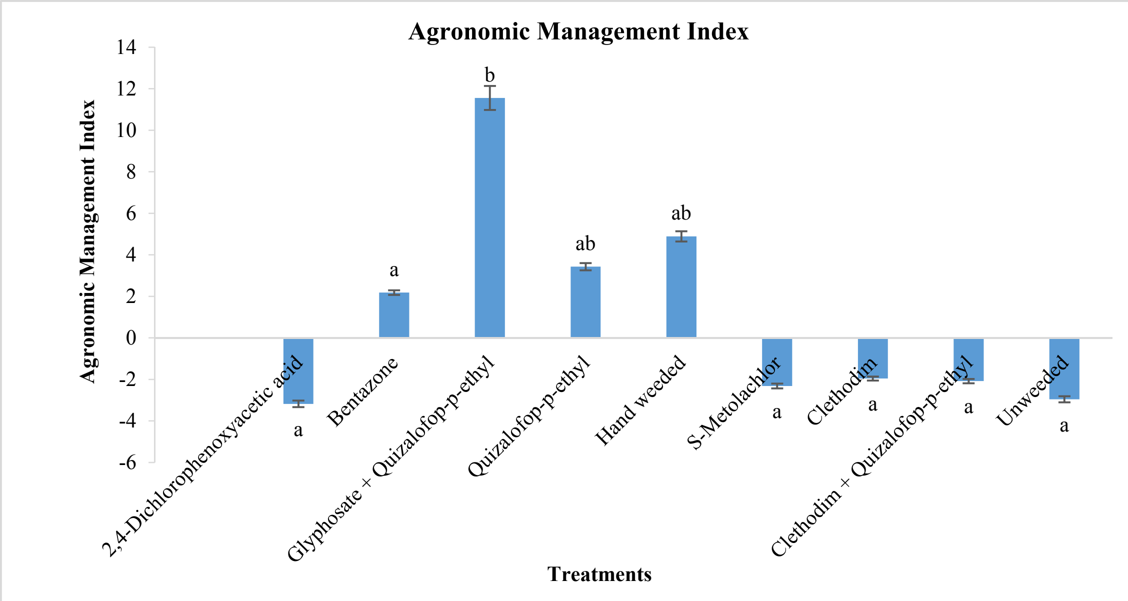

Figure 18. Showing the Agronomic Management Index of the weed control methods in groundnut during the long rains of 2021

3.6 Yield Parameters and Pod Yield of Groundnuts as Influenced by Different Weed Control Practices

Different weed control treatments statistically affected the groundnut final plant stand (Tables 1, 2, and 3). Plots treated with 2,4D had the lowest average groundnut final plant stand, 27.0 followed by Clethodim (30.7) (Tables 1, 2, and 3). Application of 2,4 D reduced the final plant stand of groundnut by 29.2%; while the combined application of Glyphosate with Quizalofop-p-ethyl reduced the groundnut plant stand marginally by 7.4% (Tables 1, 2 and 3). Different weed control treatments significantly ($P < 0.05$) affected yield parameters and yield of groundnut (Tables 1, 2, and 3). Data in Tables 1, 2 & 3 further revealed that combined application of glyphosate with Quizalofop-p-ethyl produced higher average haulm yields (282.5 kg/ha), average biological yields (2,210.0 kg/ha), average pod yield per plant (124.0 g), and average dry pod weight per ha (1724.0 kg/ha) than other treatments. Results in Tables 1, 2, and 3 further show that hand-weeded plots were second to plots treated with glyphosate combined with quizalofop-p-ethyl in average haulm yield/ha (243.5 kg/ha), biological yield/ha (1916.7 kg/ha) and pod yield /ha (1309.4 kg/ha).

Table 1. Showing plant stand, yield parameters, and yield of groundnut as influenced by different weed control methods during the long rains of 2020

Treatments	Initial plant stand	Final plant stand	Haulm wt (kg/ha)	Biological yield (kg)	Pod yield per plant (g)	Dry pod weight (kg/ha)
2,4-Dichlorophenoxyacetic acid	37.7a	26.0a	177abc	581a	34.0a	139.2ab
Bentazone	71.7a	57.3c	216bc	1209ab	89.3bc	1024.3abcd
Glyphosate + Quizalofop-p-ethyl	63.7a	58.3c	282c	2398c	127.3c	1724.1e
Quizalofop-p-ethyl	57.7a	49.0bc	188abc	1795bc	88.7c	1149.2bcd
Hand weeded	60.7a	48.0bc	243c	1918bc	106.0c	1309.2cd
S-Metolachlor	61.7a	53.3c	217bc	1703bc	128.7c	905.7abcd
Clethodim	49.0a	29.70ab	106ab	593a	42.0a	252.7ab
Clethodim+ Quizalofop-p-ethyl	71.0a	47.3bc	207abc	1074ab	56.7a	634.9abc
Unweeded	48.7a	23.3a	81a	426a	48.0ab	84.8a
LSD	*	NS	*	*	*	*

Table 2. Showing plant stand, yield parameters, and yield of groundnut as influenced by different weed control methods during the short rains of 2020

Treatments	Initial plant stand	Final plant stand	Haulm wt. (kg/ha)	Biological yield (kg)	Pod yield per plant (g)	Dry pod weight (kg/ha)
2,4-Dichlorophenoxyacetic acid	34.67a	24.0a	175.3abc	580.0a	30.0a	142.0a
Bentazone	68.67b	55.33c	214.0bc	1208ab	85.3bc	1027.3abcd
Glyphosate+ Quizalofop-p-ethyl	60.67b	56.33c	280.3c	2234.0b	123.3c	1727.2d
Quizalofop-p-ethyl	54.67ab	47.00bc	186.0abc	1711b	118.7c	1152.2bcd
Hand weeded	57.67ab	46.00bc	241.3c	1916b	102.0c	1312.2cd
S-Metolachlor	58.67b	51.33c	214.7bc	1702b	124.7c	908.7abcd
Clethodim	46.0ab	34.7ab	104.0ab	534a	38.0a	255.7ab
Clethodim+ Quizalofop-p-ethyl	68.00b	45.33bc	205.0abc	1275ab	52.7ab	627.8abc
Unweeded	45.67ab	21.33a	79.0a	527a	44.0ab	189.8ab

Table 3. Showing plant stand, yield parameters, and yield of groundnut as influenced by different weed control methods during the long rains of 2021

Treatments	Initial plant stand	Final plant stand	Haulm wt. (kg/ha)	Biological yield (kg)	Pod yield per plant (g)	Dry pod weight (kg/ha)
2,4-Dichlorophenoxyacetic acid	41.7a	31.0a	179.7abc	579a	28a	137.2a
Bentazone	75.7b	62.3c	219.0bc	1207.0ab	83.3bc	1022.3abcd
Glyphosate + Quizalofop-p-ethyl	67.7b	63.3c	285.3c	1999.0b	121.3c	1722d
Quizalofop-p-ethyl	61.7ab	54.0bc	191.0abc	171.0b	116.7c	1147.2bcd
Hand weeded	64.7ab	53.0bc	246.3c	1916.0b	100c	1307cd
S-Metolachlor	65.7ab	58.3c	219.7bc	1701.0b	122.7c	903.7abcd
Clethodim	53.0a	34.7ab	110.7ab	533.0a	36.0a	250.7ab
Clethodim+ Quizalofop-p-ethyl	75.0b	52.3bc	210.3abc	150.7ab	50.7ab	622.8abc
Unweeded	52.7ab	28.3a	84.0a	526.0a	42.0ab	184.8ab
LSD	*	NS	*	*	*	*

3.7 Economic Returns of Using Herbicides in Weed Management on Groundnut

Results in Tables 4, 5 & 6 indicate that combined application of glyphosate and quizalofop-p-ethyl produced the highest average total revenues (8,211,746/=) followed by hand weeding (6,235,714.3/=) then quizalofop-p-ethyl (sole) (5,473,809.3/=). Similarly, the combined application of glyphosate and quizalofop-p-ethyl produced the highest average gross margins (7,937,746/=) followed by hand weeding (5,494,714.3/= then quizalofop-p-ethyl (5,323,809.3/=). On the contrary, the sole application of quizalofop-p-ethyl had the highest average B:C ratio (36.49) followed by the combined application of glyphosate and quizalofop-p-ethyl (29.97) then hand weeding that produced the lowest (8.41).

Table 4. Showing economic returns of growing groundnuts as influenced by different weed control methods during the long rains of 2020

Treatments	Dry pod weight (kg/ha)	Total costs (UGX)	Total revenues (UGX)	Gross margins (UGX)	B:C ratio
2,4-Dichlorophenoxyacetic acid	139.2ab	35,560	662,698 a	627,138ab	18.64abc
Bentazone	1024.3abcd	373,464	4,877,778abcd	4,504,314abcd	13.06ab
Glyphosate + Quizalofop-p-ethyl	1724.1e	274,000	8,209,841d	7,935,841d	29.96bc
Quizalofop-p-ethyl	1149.2bcd	150,000	5,472,222bcd	5,322,222bcd	36.48c
Hand weeded	1309.2cd	741,000	6,234,127cd	5,493,127cd	8.41a
S-Metolachlor	905.7abcd	240,000	4,312,698abcd	4,072,698abcd	17.97abc
Clethodim	252.7ab	135,850	1,203,175ab	1,067,325abc	8.86a
Clethodim + Quizalofop-p-ethyl	634.9abc	260,738	3,023,333abc	2,762,595abc	11.60ab
Unweeded Unweeded	184.8a	0	880,154ab	880,154ab	17.72abc
LSD	*	ns	*	*	*

Note. Along the columns values having similar letters are not significantly different; while values with different letters differ significantly at P < 0.05. * significant at a 5% level of probability while ns not significant at a 5% level of probability. The exchange rate at the period of experimentation = UGX 3919.96 to 1 US$.

Table 5. Showing economic returns of growing groundnuts as influenced by different weed control methods during the short rains of 2020

Treatments	Dry pod weight (kg/ha)	Total costs (UGX)	Total revenues (UGX)	Gross margins (UGX)	B:C ratio
2,4-Dichlorophenoxyacetic acid	142.0a	35,560	676,984a	641,424a	19.04abc
Bentazone	1027.3abcd	373,464	4,892,063abcd	4,518,599abc	13.10ab
Glyphosate + Quizalofop-p-ethyl	1727.2d	274,000	8,224,603d	7,950,603c	30.02bc
Quizalofop-p-ethyl	1152.2bcd	150,000	5,486,508bcd	5,336,508abc	36.58c
Hand weeded	1312.2cd	741,000	6,248,413cd	5,507,413bc	8.43a
S-Metolachlor	908.7abcd	240,000	4,326,984abcd	4,086,984abc	18.03abc
Clethodim	255.7ab	135,850	1,217,460ab	1,081,610ab	8.96a
Clethodim + Quizalofop-p-ethyl	627.8abc	260,738	2,989,683abc	2,728,945ab	11.47ab
Unweeded	189.8ab	0	903,968ab	903,968ab	18.20abc
LSD	*	ns	*	*	*

Note. Along the columns values having similar letters are not significantly different; while values with different letters differ significantly at P < 0.05. * significant at a 5% level of probability while ns not significant at a 5% level of probability. The exchange rate at the period of experimentation; UGX 3706 = 1 US$.

Table 6. Showing economic returns of growing groundnuts as influenced by different weed control methods during the long rains of 2021

Treatments	Dry pod weight (kg/ha)	Total costs (UGX)	Total revenues (UGX)	Gross margins (UGX)	B:C ratio
2,4-Dichlorophenoxyacetic acid	137.2a	35,560	653,175a	617,615a	18.37abc
Bentazone	1022.3abcd	373,464	4,868,254abcd	4,494,790abc	13.04ab
Glyphosate + Quizalofop-p-ethyl	1722d	274,000	8,200,794d	7,926,794c	29.93bc
Quizalofop-p-ethyl	1147.2bcd	150,000	5,462,698bcd	5,312,698abc	36.42c
Hand weeded	1307cd	741,000	6,224,603cd	5,483,603bc	8.40a
S-Metolachlor	903.7abcd	240,000	4,303,175abcd	4,063,175	17.93abc
Clethodim	250.7ab	135,850	1,193,651ab	1,057,801ab	8.79a
Clethodim + Quizalofop-p-ethyl	622.8abc	260,738	2,965,873abc	2,705,135ab	11.37ab
Unweeded	184.8ab	0	880,159ab	880,159ab	18.03abc
LS	*	ns	*	*	*

Note. Along the columns values having similar letters are not significantly different; while values with different letters differ significantly at $P < 0.05$. * significant at a 5% level of probability, while ns is not significant at a 5% level of probability. The exchange rate at the period of experimentation; UGX 3544 = 1 US$.

3.8 Overall Treatment Effects Across the three Seasons of Experimentation

Results in tables 7, 8, and 9 indicate that dry pod weight, total revenue, and gross margin were affected by different weed control methods in the following order starting with one that had the lowest rank for all the three parameters; 2,4-Dicholorophenoxyacetic Acid (1), Unweeded (2), Clethodim (3), Clethodim + quizalofop-p-ethyl (4), S-metolachlor (5), Bentazone (6), quizalofop-p-ethyl (7), Hand weeded (8) and glyphosate + quizalofop-p-ethyl (9).

Table 7. Table showing ranked treatment effect on dry pod weight, total revenues, and gross margin during the long rains of 2020

Treatments	Dry_Pod_Wt_kg_ha	Total_revenues_UGX	Gross_margins_UGX	Rank
2,4-Dichlorophenoxyacetic acid	142	676984	641424	1
Bentazone	1027.3	4892063	4518599	6
Glyphosate + Quizalofop-p-ethyl	1727.2	8224603	7950603	9
Quizalofop-p-ethyl	1152.2	5486508	5336508	7
Hand weeded	1312.2	6248413	5507413	8
S-Metolachlor	908.7	4326984	4086984	5
Clethodim	255.7	1217460	1081610	3
Clethodim + Quizalofop-p-ethyl	627.8	2989683	2728945	4
Unweeded	189.8	903968	903968	2

Table 8. Table showing ranked treatment effect on dry pod weight, total revenues, and gross margin during the short rains of 2020

Treatments	Dry_Pod_Wt_kg_ha	Total_revenues_UGX	Gross_margins_UGX	Rank
2,4-Dichlorophenoxyacetic acid	137.2	653175	617615	1
Bentazone	1022.3	4868254	4494790	6
Glyphosate + Quizalofop-p-ethyl	1722	8200794	7926794	9
Quizalofop-p-ethyl	1147.2	5,462,69	5312698	7
Hand weeded	1307	6224603	5483603	8
S-Metolachlor	903.7	4303175	4063175	5
Clethodim	250.7	1193651	1057801	3
Clethodim + Quizalofop-p-ethyl	622.8	2965873	2705135	4
Unweeded	184.8	880159	880159	2

Table 9. Table showing ranked treatment effect on dry pod weight, total revenues, and gross margin during the long rains of 2021

Treatments	Dry_Pod_Wt_kg_ha	Total_revenues_UGX	Gross_margins_UGX	Rank
2,4-Dichlorophenoxyacetic acid	139.2	662698	627138	1
Bentazone	1024.3	4877778	4504314	6
Glyphosate + Quizalofop-p-ethyl	1724.1	8209841	7935841	9
Quizalofop-p-ethyl	1149.2	5472222	5322222	7
Hand weeded	1309.2	6234127	5493127	8
S-Metolachlor	905.7	4312698	4072698	5
Clethodim	252.7	1203175	1067325	3
Clethodim + Quizalofop-p-ethyl	634.9	3023333	2762595	4
Unweeded	184.8	880154	880154	2

4. Discussion

Significantly higher weed density of sedges (SG) than grasses (GR) and broadleaved weeds (BL) in plots treated with different herbicides could be attributed to their high phytotoxicity to only the BL and GR weed species compared to sedges. Consequently, this could have caused an overgrowth of sedges due to limited competition from other weed species, hence their high numbers. Chauhan et al. (2022) similarly reported that most herbicides are less effective against sedges and even those that can kill 85-100% of sedges require applying at higher doses that are not cost-effective. The higher weed density of GR in plots treated with 2,4 D and S-Metolachlor is probably attributed to their selective phytotoxicity against BL. However, the higher weed density of BL in plots treated with glyphosate combined with quizalofop-p-ethyl and quizalofop-p-ethyl (sole) is probably attributable to their specific phytotoxicity to grass. Mundra et al. (2012) in their weed experiment on Blackgram similarly found that plots treated with Quizalofop-p-ethyl had higher BL and attributed it to its less phytotoxicity to broadleaved weeds; while Mishra et al.2016 reported that plots treated with 2,4 D had higher GR weed density and they similarly attributed it to selective phytotoxicity of 2,4D against broad-leaved weeds.

Significant reduction in weed biomass in hand-weeded plots and those treated with a combination of glyphosate and quizalofop-p-ethyl is attributed to their effectiveness in controlling all weeds. This conforms with findings by Mundra et al. (2012) who observed that the application of quizalofop-p-ethyl on blackgram significantly reduced weed weight compared to other herbicides; while hand weeding had the highest reduction of weed biomass. They equally attributed this to their effectiveness in controlling most weed species. Higher weed biomass observed in plots treated with 2,4D is attributable to its selective phytotoxicity against broad-leaved weeds which results in vigorous growth of grass species. Consequently, this results in a higher biomass. Mishra et al. (2016) similarly observed that applying 2,4D on weeds results in enhanced biomass. They equally attributed this to selective phytotoxicity of 2,4D against broadleaved weeds that led to overgrowth of grass left behind thus resulting in enhanced biomass.

Lower weed index (WI) in plots treated with a combination of glyphosate and quizalofop-p-ethyl and quizalofop-p-ethyl applied alone is attributable to their ability to kill weeds of all classes. Consequently, this results in small or no weed growth thus contributing to low WI. This conforms with Shittu et al. (2023) who reported that the combined application of imazethapyr and pendimethalin on cowpea had a low WI which they also attributed to the phytotoxicity of the two herbicides to all classes of weeds, where weed growth is significantly reduced thus resulting in low weed index. On the contrary, significantly higher WI (67.7%) in plots treated with 2,4 D compared to other herbicides is attributable to their ability to kill only broadleaved weeds resulting in overgrowth of grass weed species. This is consistent with findings by Renze et al. (2011) who reported that the application of bromoxynil on legume-cereal crop mixtures killed only broad-leaved weeds resulting in significantly higher WI. They similarly attributed it to the vigorous growth of grass left behind by 2,4D.

The Highest WCE in hand-weeded plots could be attributed to its efficiency in the management of weeds; while, higher WCE observed in plots treated with glyphosate combined with quizalofop-p-ethyl compared to other herbicides could be attributed to its broad-spectrum phytotoxicity to all classes of weeds. On the contrary, low WCE observed in plots treated with 2,4 Dichlorophenoxyacetic acid could be associated with its ability to kill only broad-leaved weeds thus resulting in the accumulation of grass weeds. Mishra et al. (2016) and Shittu et al.

(2023) similarly found that hand weeding had higher WCE followed by herbicides that kill all classes of weeds, unlike 2,4 Dichlorophenoxyacetic acid that selectively kills only broadleaved weeds.

Significantly a higher AMI observed in plots treated with a combined application of glyphosate and guizalofop-P-ethyl could be attributed to the broad-spectrum phytotoxic effect of this treatment on weeds in which all weeds are effectively killed thus ensuring better crop growth and yields; while the lowest AMI observed in plots treated with 2,4 D may be attributable to its selective phytotoxicity to only broadleaved weeds. Thus promoting the accumulation of grass weeds and consequently resulting in low crop growth and yields. Mondal et al. (2020) equally observed low AMI in plots of rice treated with sole herbicides that kill only one class of weeds causing an accumulation of weeds that are selected against thus resulting in low rice growth and yields. They further reported that combined herbicides with a broad spectrum effect kill most weeds resulting in high AMI due to enhanced rice growth and yields. They similarly attributed higher AMI to efficient control of weeds in a rice field by applying a combination of herbicides that kill all weeds thus enhancing crop growth and yields.

Low groundnut plant stand observed in plots treated with 2,4D could be attributed to the death of some groundnut plants due to its High phytotoxicity to broadleaved plants like groundnut. On the contrary, the high final groundnut plant stand observed in plots treated with quizalofop-p-ethyl could be attributed to its less phytotoxicity to broadleaved plants like groundnut. This conforms with Mundra et al., (2012) who reported that the application of 2,4 D significantly reduced the dry weight and plant height of greengram and equally attributed it to the high phytotoxicity of 2,4D to broadleaved plants like greengram.

Significantly higher haulm yields, biological yields, pod yield per plant, and dry pod yield per ha due to the combined application of Glyphosate and quizalofop-p-ethyl can be attributable to its effectiveness in killing weeds. Consequently, promoting vigorous growth of the groundnut plant resulting in higher yields. Mayerova et al. (2018) similarly observed that the application of herbicides like sulfonylureas, significantly increased groundnut yields between 13 and 50% compared with unweeded plots and they equally attributed it to the efficient control of weeds by the herbicide applied.

The highest total revenues and gross margins observed in plots treated with a combination of glyphosate and quizalofop-p-ethyl followed by hand weeding then quizalofop-p-ethyl (sole) is attributable to their efficiency in weed management that resulted in higher pod yields that in turn caused higher gross margins at the sale of the produce. Ramaligam et al. (2013) and Samant et al. (2014) similarly found that combined application of pre-emergence herbicide (Oxfluorfen) and post-emergence herbicide (Imazethapyr and quizalofop-P-ethyl significantly increased income from groundnuts due to increased yields also resulting from efficient weed management. The highest B: C ratio observed in plots treated with Quizalofop-P-ethyl alone could be attributed to the low amount of funds involved in the purchase of a single herbicide compared to a combination of glyphosate and quizalofop-p-ethyl where two herbicides are bought. On the contrary, the lowest B: C ratio observed in hand-weeded plots could be attributed to the high cost of labour.

5. Conclusion

Pre-emergence application of glyphosate followed by three subsequent post-emergence applications of quizalofop-p-ethyl; effectively controlled weeds resulting in higher groundnut pod yields, total revenue, and gross margin. The above treatment was also the most profitable due to its high gross margin. Pre-emergence application of 2,4 Dichlorophenoxy acetic acid alone exhibited poor weed control resulting in the lowest pod yield, total revenue, and gross margin. However, the post-emergence application of quizalofop-p-ethyl alone was the most cost-effective in managing weeds in groundnuts due to its high benefit-cost ratio. This study further shows that three-hand weedings can be good for areas where labour is not expensive and scarce. However, the high cost and human drudgery associated with it undermine its use in managing weeds in groundnuts. Weeds in groundnuts can best be managed by applying pre-emergence herbicide (Glyphosate) then followed by subsequent post-emergence application of a selective herbicide (Quizalofop-P-ethyl).

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Authors Contributions

Dr. Anguria Paul and Dr. Essegbemon Akpo were responsible for study design and revising. Dr Anguria Paul was also responsible for data collection. Dr Anguria Paul drafted the manuscript and Dr. Essegbemon Akpo, Dr. Christopher Ojiewo and Dr. Michael A. Ugen revised it. All authors read and approved the final manuscript. All authors immensely contributed to the production of this article.

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