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Productivity and Economic Benefits of Using Different Rates of Lumax 537.5 SE for Weed Control in Maize in a Transition Agro-ecological Zone of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author VYA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EKA and HKD managed the analyses of the study. Authors VYA and EKA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A study on the productivity and economic benefits of various rates of Lumax 537.5 SE for weed control in maize were conducted during the 2009 and 2010 cropping seasons at the Multipurpose Research Centre of the University of Education, Winneba, Mampong-Ashanti from September-December, 2009 and April-July, 2010. The treatments were Lumax 537.5 SE at rates of 2, 4, 6, and 8l/ha and Hoe-weeded with Unweeded treatment added as a control. Lumax at all rates and the Hoe-weeded treatments had more than 22% higher maize grain yield than the Unweeded control in both years. The 4l Lumax/ha gave the highest net benefit of USD1432.9/ha and USD1931.02/ha in 2009 and 2010, respectively compared to all the other treatments. The Hoe-weeded and Lumax rates at 6 l/ha and 8 l/ha had lower net benefits of USD1356.25/ha, USD1407.88/ha and USD1366.23/ha respectively in 2009, USD1830.91/ha, USD1866.41/ha, USD1834.29/ha respectively in 2010, but higher total variable costs of USD218.75/ha, USD198.63/ha and

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USD233.28/ha, respectively in 2009 and USD245.84/ha, USD224.54/ha and USD260.22/ha respectively in 2010 compared to the 4l Lumax/ha; and therefore were dominated by the latter. The 4l Lumax/ha gave marginal rates of returns of 544% and 714% over the 2l Lumax/ha in 2009 and 2010, respectively. It was concluded that Lumax 537.5 SE at 4l/ha was the optimum rate for better weed control and profitability for maize production in the transitional agro-ecological zone of Ghana.

Keywords: Lumax; maize grain yield; net benefit; marginal rate of return.

1. INTRODUCTION

Maize (*Zea mays* L.) is a cereal crop adapted to a wide range of environmental conditions and is cultivated in all agro-ecologies of West and Central Africa [1]. It has many different uses including food for humans, feed for livestock, and raw materials for agro-allied industries.

Maize is extensively cultivated in Ghana, plays a critical role in ensuring food security, and accounts for 50-60% of the country's cereal production [2]. The vast majority of maize is produced by smallholder farmers under rainfed conditions, leading to annual variation in yield. Maize yields in Ghana average approximately 1.9 metric tons per hectare compared to a production potential of 6 metric tons per hectare [3].

Weeds have over the years remained one of the greatest production constraints for maize farmers especially in the tropics [4]. Weed control is a very important management practice for optimum growth and yield of maize. Weeds are generally controlled using cultural (hand or hoe–weeding), mechanical (slashing), chemical (pre-plant, pre or post-emergence herbicides) and integrated management practices [4].

The most popular weed management practices in maize, such as hoe- weeding, pulling or slashing usually involve a substantial input of human labour [5]. However, the high cost and unavailability of labour usually cause delayed and ineffective weeding that often results in substantial crop yield losses [6]. Manual weeding represents about 50%-80% of the total labour budget [7]. [6] and may also cause mechanical injury to the maize roots and reduce the plant stand and crop yields.

Chemical control is a better alternative to manual weeding because it is cheaper, faster, and gives effective control of weeds [6]. [4] also reported that chemical weed control is more economical compared to manual weeding. [8,9] also added that it is economically rational for farmers to move from traditional to chemical weed control in maize production to improve effectiveness and efficiency. Herbicide use has therefore resulted in higher yields and profits from production. Many researchers have in the past focused on identifying management practices that could suppress weeds without paying much attention to the economic efficiency of these techniques.

Lumax 537.5 SE is one of the most recently formulated pre-emergence herbicides that have been introduced into the Ghanaian market for maize production. Lumax® herbicide belongs to benzoylcyloheaxanedione class of herbicides. Lumax 537.5 SE is a susplo-emulsifiable (SE) herbicide targeted at annual broad-leaf weeds and grasses in maize and sugarcane at the application rate of 4l/ha [10] Lumax 537.5 SE is a combination of the active ingredients: 2.94% Mesotrione (2-[4-(methylsulfonyl)-2-nitrobenzoyl]-1,3-cyclohexanedione), 29.4% S-metolachlor [Acetamide, 2-chloro-N-(2-ethyl-6-methyl phenyl)=N-methoxy-1-methylethyl]-,(S), 11% Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and other ingredients (56.66%) [11].

The main objective of the maize production enterprise like every other business is profit maximization by the farmer. However, there is paucity of information on the optimum use rate of Lumax 537.5 SE to control weeds for high maize grain yield and economic returns in Ghana. It is therefore important to have a reasonable understanding of the economic benefits of production investment on this crop. The objective of this study was to assess the productivity and economic benefits of various rates of Lumax 537.5 SE for weed control in maize.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted at the Multipurpose Research Centre of the University of Education, Winneba, College of Agriculture Education, Mampong-Ashanti from September-December, 2009 and April-July, 2010. Mampong-Ashanti (7°45'N, 1°24'W) lies at an altitude of 402 m above sea level and in the transitional agro-ecological zone between the rainforest of the south and the Guinea Savanna of the north of Ghana. The area experiences bimodal rainfall regime. The major rainy season begins from mid-March and ends in July. The minor season begins in August and ends in mid-November. There is a dry spell of harmattan season from December to March. The soils belong to the Bediese series (which are sandy loam, well-drained with a thin layer of organic matter, deep yellowish red, friable and free from stones [12] and are classified as Chromic Luvisol according to the FAO/UNESCO soil classification [13].

2.2 Field Procedures

The land was manually cleared with cutlass, stumped and levelled. Seeds of the maize cultivar "Akposoe" obtained from the Crops Research Institute, Fumesua were sown manually at three seeds per hill spaced at 40 cm in rows 75 cm apart, in plots of six rows, 5.6 m in length on 15th September, 2009 and 17th April, 2010.

At 2 weeks after planting (WAP), the plants were thinned to two per hill for a final density of 66,666 plants/ha. The experiment was set up as a randomized complete block design with six treatments and four replications. Treatments were four rates of pre-emergence application of Lumax 537.5 SE at 2, 4, 6, 8l/ha and Hoe-weeded with Unweeded treatment as control. The herbicide was applied the same day as seeds were sown with a CP 15 knapsack sprayer calibrated to deliver 300l/ha spray solution.

The hoe-weeded plots were weeded at 3WAP and 6 WAP. Basal fertilizer (45kg/ha of NPK [15:20:15]) was applied 2 WAP and urea (45 kg N/ha) was side-dressed to the maize 5 WAP in both years. Maize was harvested from a net plot of 7.8 m^2 on the 12th December, 2009 and 15th July, 2010 during the first and second experiments, respectively.

2.3 Data Collection and Statistical Analysis

Data on rainfall at the experimental site was collected during the two cropping seasons. Maize grain yields were adjusted to 12% moisture content using a Dickey-John moisture tester (Dickey- John Corporation, Auburn IL, USA, Model 14998). The data collected on maize grain yield was subjected to statistical analysis using Analysis of Variance and the SAS Statistical Package [14]. The Least Significant Difference (LSD) test was used to compare all treatments means.

The prices for both inputs and outputs were collected in both years from the farmers and local markets. Farm gate price of maize was USD350/t in 2009 and USD355/t in 2010. The cost of Lumax 537.5 SE was USD17.5/litre and USD17.75/litre in 2009 and 2010, respectively. Labour for Lumax application was 2 man-days/ha. Labour for hauling water to mix with Lumax was 1 man-day/ha. Labour for 1 hoe-weeding was 20 man-days/ha. The cost of labour was USD3.5/man-day, and the cost of sprayer rental was USD2.8/ha in 2009 while in 2010, the cost of labour was USD3.55/man-day, and the cost of sprayer rental was USD2.84/ha. The partial budget analysis was used to estimate the net benefit (NB) of the treatments and the marginal rates of return (MRR) to determine the benefit to farmers [15]. The net benefit and MRR were calculated as: Net benefit (NB) = Total Gross Benefit (TGB)-Total Variable Cost (TVC). MRR= (ΔNB / ΔTVC) x 100. The MRR is the increased benefit of a treatment as a percentage of the increased cost. Dominance analysis was also carried out. A treatment with a lower NB but a higher TVC compared to another treatment is said to be dominated. No capital costs such as land and management charges, interest on operational capital, depreciation of machinery and equipment, and other overheads were considered. The value of the crop was at harvesting period; therefore, no cost was borne for storage.

3. RESULTS AND DISCUSSION

3.1 Maize Grain Yield

Maize grain yields were higher in 2010 than in 2009 (Table 1). Grain yield of maize ranged from 3.07 to 5.10 t/ha and 4.44 to 6.55 t/ha for 2009 and 2010, respectively with yield of Unweeded plots in 2010 even higher than those plots where 2l Lumax/ha was applied in 2009. The largedifference in yield for both years can be attributed to variability of rainfall at the site during both cropping seasons (Table 2). In 2009, there was a sharp drop in rainfall from 138.6 mm in October to 45.2 mm in November when the crop had reached its tasseling stage amidst drought whilst at the same growth stage in 2010; maize

Table 1. Effect of herbicide treatments and hoe-weeded on maize grain yield in 2009 and 2010

Treatment	Grain yield (t/ha)		Mean grain yield (t/ha)	% Mean grain yield increase
	2009	2010	2009 - 2010	2009-2010
Unweeded	3.07	4.44	3.76	0.00
2l Lumax/ha	4.01	5.20	4.61	22.61
4l Lumax/ha	5.07	6.50	5.79	54.00
6l Lumax /ha	5.10	6.52	5.82	54.52
8l Lumax/ha	5.08	6.55	5.81	54.79
Hoe-weeded	5.00	6.50	5.75	52.92
Mean	4.56	5.95	5.26	39.89
LSD (0.05)	0.42	0.86		
CV (%)	6.30	9.53		

Table 2. Monthly rainfall at the site during the 2009 and 2010 cropping seasons

2009 cropping season		2010 cropping season	
Month	Total monthly Rainfall (mm)	Month	Total monthly Rainfall (mm)
September	99.3	April	77.3
October	138.6	May	108.8
November	45.2	June	225.8
December	33.4	July	83
Total	316.5	Total	494.9
Mean	79.1	Mean	123.7

Source: Meteorological services department, Ashanti-Mampong

received adequate rainfall of 108.8-225.8 mm from May to June, respectively. The most crucial time of water stress in maize crop is ten to fifteen days before and after flowering. At this stage, if the water deficit occurs then the grain yield decreases two to three times more than the water deficit in another growing stage [16].

A significant (P<0.05) effect of different weed control treatments was observed on grain yield of maize during both years (Table 1). When pooled, maize grain yield increased by 22.61-54.79% probably because of effective weed control by Lumax treatments at rates 2-8l/ha and Hoe-weeded treatment that might have significantly reduced competition for nutrients, water and solar radiation compared with Unweeded control treatment. The results of this study support [17] who demonstrated that hand weeding and chemical method of weed control in maize gave 32-34% increase in grain yield of maize as compared to weedy check. Similarly, [18] reported that Lumax at five rates: 1.88-2.96 kg a.i./ha significantly reduced weed density and biomass and increased grain yield by 12-22% while [19] reported that application of selective herbicides provided 65 to 90% weed control and 100 to 150% more maize grain yields than Unweeded control.

Among the herbicide treatments, the 2l Lumax/ha treatment produced the least grain yields (Table 1). Reduced yields under 2l Lumax/ha are due to the lack of adequate suppression or control of weeds.

The highest grain yields were in treatments with 4-8l/ha of Lumax and the Hoe weeded representing increased grain yield of 52.92-54.79% when pooled (Table 1). Higher grain yields under treatments of 4l Lumax/ha, 6l Lumax/ha, 8l Lumax/ha and Hoe-weeded may be due to the fact that their effective control of weeds lead to direct increase in uptake of nutrient and thereby proper growth and development of crop which resulted in increase in 100-seed weight and ultimately resulting in increased grain yield. The similarity in higher yields among the Hoe-weeded control and Lumax dosages of 4, 6 and 8l/ha suggests that these treatments are similarly adequate to reduce the weed densities to non-competitive levels.

Maize grain yield from the Hoe-weeded treatment was among the highest because hoe-weeding provides clean seedbed and loosens the soil. The cut weeds left in the soil may decompose and add organic matter to the soil for enhanced growth and yield of maize.

3.2 Adjusted Grain Yield

The grain yields were adjusted by 10% downward in the economic analysis (Tables 3 and 4) to approximate the yield that farmers can obtain on their farms [20]. This was necessary to prevent overestimation of the returns that farmers are likely to obtain from a treatment because the yields on farmers' fields are lower than those obtained by researchers. Experimental yields are higher than farmers' yields because of higher management level which includes recommended number of stands, timely weeding, timely application of fertilizers and pesticides, recommended dosages of fertilizer and pesticides, precision in harvesting dates and better harvesting methods, and smaller plot sizes [21].

3.3 Total Gross Benefit (TGB)

TGB per hectare or total revenue for the weed control treatments ranged from USD966 to USD1606.5/ha in 2009 and from USD1420 to 2094.5/ha in 2010 (Tables 3 and 4). The difference in the results of total gross benefits among the treatments (Table 1) is attributed to the differences in yield recorded by the various treatments in both years, as a result, their respective weed control efficiencies. The highest total gross benefit in 2009 was recorded by 6l Lumax/ha (USD1606.5/ha), followed by 8l Lumax/ha (USD1599.5/ha) while 4l Lumax/ha and Hoe-weeded gave USD1596/ha and USD1575/ha, respectively. The Unweeded check and the 2l Lumax/ha recorded the lowest total gross benefit of USD966/ha and USD1263.5/ha, respectively compared to the other treatments in 2009. However, in 2010, the 8l Lumax/ha treatment gave the highest total gross benefit of USD2094.5/ha followed by the 6l Lumax/ha (USD2090.95/ha) while 4l Lumax/ha and Hoe-weeded gave USD2076.75/ha each. Again, the Unweeded control and the 2l Lumax/ha gave the lowest total gross benefit of USD1420/ha and USD1661.4/ha, respectively in 2010, possibly due to their ineffective weed control to generate higher maize grain yield as well as higher TGB as compared to the other treatments.

3.4 Total Variable Cost

The total variable cost (TVC) or cost of production ranged from USD48.3 to USD233.28/ha in 2009 while it was from USD71 to USD260.22/ha in 2010 (Tables 3 and 4). The use of 8l Lumax/ha was more costly than hoe-weeding in both years as 8l Lumax/ha recorded the highest TVC of USD233.28/ha and USD260.22/ha followed by the Hoe- weeded treatment at USD218.75/ha and USD245.84/ha in 2009 and 2010, respectively. However, the Hoe- weeded incurred higher cost of production than 4l Lumax/ha and 6l Lumax/ha treatments which recorded TVC of USD163.1/ha and USD198.63/ha in 2009 and USD188.33/ha and USD224.54/ha in 2010, respectively. Compared to 4l Lumax/ha and 6l Lumax/ha treatments, hoe-weeding can be considered to be more expensive. This endorses the reports of [6] that hoe weeding is expensive. The Unweeded and the 2l Lumax/ha treatments incurred the least cost of production of USD48.3/ha and USD111.48/ha, respectively in 2009 as well as USD71/ha and USD132.06/ha, respectively in 2010.

3.5 Net Benefits

Generally, all treatments were economically attractive, as they had positive net benefits (Tables 3 and 4). The highest net benefit or profit of USD1432.9/ha and USD1931.02/ha was obtained from 4l Lumax/ha in 2009 and 2010, respectively. Lumax use rates at 4, 6 and 8l/ha gave more net benefits of USD1432.9/ha, USD1407.88/ha and USD1366.23/ha, respectively in 2009, and USD1931.02/ha, USD1866.41/ha and USD1834.29/ha, respectively in 2010 compared Hoe- weeded treatment which achieved USD1356.25/ha and USD1830.91/ha in 2009 and 2010, respectively. This indicates that the use of Lumax ranging from 4l/ha to 8l/ha is more profitable than hoe-weeding because the difference between the cost of maize production and the gross benefit obtained from hoe- weeding is lower than those of 4 to 8l Lumax/ha. It was found that Hoe-weeding is, however, more economically viable than application of 2l Lumax /ha, possibly because the latter could not control weeds effectively to produce enough maize as the Hoe-weeded did.

The lowest net benefit of USD917.7/ha and USD1349/ha was recorded by the Unweeded check in 2009 and 2010, respectively, as expected. Similarly, [17] reported that all the treatments in their study gave higher net benefit as compared to the control weedy check-in maize production.

Table 3. Partial budget analysis for maize as affected by Lumax 537.5 SE rates and hoe weeding, 2009

Gross benefits	**Unweeded**	**2l Lumax/ha**	**4l Lumax/ha**	**6l Lumax/ha**	**8l Lumax/ha**	**Hoe-Weeded**
Yield (t/ha)	3.07	4.01	5.07	5.1	5.08	5
Adjusted yield (90%) (t/ha)	2.76	3.61	4.56	4.59	4.57	4.5
Total Gross Benefit (TGB)(USD /ha)	966	1263.5	1596	1606.5	1599.5	1575
Variable Cost						
Cost of Lumax 537.5 SE (USD)	0	35	70	195	140	0
Cost of labour for application (USD)	0	7	7	7	7	0
Cost of labour for hauling water(USD)	0	3.5	3.5	3.5	3.5	0
Cost of labour for hoe weeding(USD)	0	0	0	0	0	140
Sprayer rental (USD/ha)	0	2.8	2.8	2.8	2.8	0
Cost of shelling (USD)	48.3	63.18	79.8	80.33	79.98	78.75
Total Variable Cost (TVC)(USD/ha)	48.3	111.48	163.1	198.63	233.28	218.75
Net Benefit (TGB-TVC)(USD/ha)	917.7	1152.03	1432.9	1407.88	1366.23	1356.25
Marginal Rate of Return (MRR)	**Unweeded**	**2l Lumax/ha**	**4l Lumax/ha**	**6l Lumax/ha**	**Hoe-Weeded**	**8l Lumax/ha**
TVC (USD/ha)	48.3	111.48	163.1	198.63	218.75	233.28
Net Benefit (USD/ha)	917.7	1152.03	1432.9	1407.88	1356.25	1366.23
MRR (%) = (ΔNB / ΔTVC) x 100		371	544	D -70#	D -257##	D 69###

D = Dominated; # = MRR of 6l Lumax/ha over 4l Lumax/ha;
= MRR of Hoe-weeded over 6l Lumax/ha; ### = 8l Lumax/ha over Hoe-weeded.
GH¢1.00 = USD 0.70 in 2009

Table 4. Partial budget analysis for maize as affected by Lumax 537.5 SE rates and hoe weeding, 2010

Gross benefits	**Unweeded**	**2l Lumax/ha**	**4l Lumax/ha**	**6l Lumax/ha**	**8l Lumax/ha**	**Hoe-Weeded**
Yield (t/ha)	4.44	5.20	6.50	6.52	6.55	6.50
Adjusted yield (90%) (t/ha)	4.00	4.68	5.85	5.89	5.90	5.85
Total Gross Benefit (TGB)(USD /ha)	1420	1661.4	2076.75	2090.95	2094.5	2076.75
Variable Cost						
Cost of Lumax 537.5 SE (USD)	0	35.5	71	106.5	142	0
Cost of labour for application (USD)	0	7.1	7.1	7.1	7.1	0
Cost of labour for hauling water(USD)	0	3.55	3.55	3.55	3.55	0
Cost of labour for hoe weeding(USD)	0	0	0	0	0	142
Sprayer rental (USD/ha)	0	2.8	2.8	2.8	2.8	0
Cost of shelling (USD)	71	83.07	103.84	104.55	104.73	103.84
Total Variable Cost (TVC)(USD/ha)	71	132.06	188.33	224.54	260.22	245.84
Net Benefit (TGB-TVC)(USD/ha)	1349	1529.34	1931.02	1866.41	1834.29	1830.91
Marginal Rate of Return (MRR)	**Unweeded**	**2l Lumax/ha**	**4l Lumax/ha**	**6l Lumax/ha**	**Hoe-Weeded**	**8l Lumax/ha**
TVC (USD/ha)	71	132.06	188.33	224.54	245.84	260.22
Net Benefit (USD/ha)	1349	1529.34	1931.02	1866.41	1830.91	1834.29
MRR (%) = (∆NB / ∆TVC) x 100		295	714	D -178#	D -167##	D 24###

D = Dominated; #= MRR of 6l Lumax/ha over 4l Lumax/ha;
##= MRR of Hoe-weeded over 6l Lumax/ha; ### = 8l Lumax/ha over Hoe-weeded.
GH¢1.00 = USD 0.71 in 2010

3.6 Dominance Analysis

The dominance analysis showed that the 6l Lumax/ha, Hoe-weeded and 8l Lumax/ha treatments had lower net benefits but higher total variable costs than the 4l Lumax/ha treatment in both 2009 and 2010 (Tables 3 and 4), and therefore, were dominated by the latter. Hence, the 4l Lumax/ha was more profitable than the 6l Lumax/ha, Hoe-weeded and 8l Lumax/ha. In relation to the 4l Lumax/ha, the dominated treatments (6l Lumax/ha, Hoe-weeded and 8l Lumax/ha) need not be considered further in the analysis and can be discarded. Under normal circumstances, a farmer will never choose one of these dominated alternatives. The dominated alternatives are eliminated from further analysis and un-dominated alternatives are used to compute Marginal Rates of Returns (MRR) [22].

The Hoe-weeded was dominated by and hence less profitable than the 6l Lumax/ha treatment because the Hoe-weeded had lower net benefits of USD1349/ha and UDS1830.91/ha but higher total variable costs of USD218.75/ha and USD245.84/ha than the 6l Lumax/ha treatment which recorded net benefits of USD1407.88/ha and UDS1866.41/ha but total variable costs of USD198.63/ha and USD224.54/ha in 2009 and 2010, respectively. The use rates of 4l Lumax/ha and 6l Lumax/ha were, therefore, more lucrative options than the Hoe-weeded treatment and thereby demonstrated a level of superiority of the herbicide over manual weeding for better economic returns. These findings support [23] who reported that the use of herbicides resulted in significantly greater maize grain yields and economic benefit than hand-weeding in sole maize crop. Specifically, [23] noted that the increase in yield was 25-50% with a mean of 33%, and economic benefits of 33% from the use of herbicide weed management compared with hand-weeding in smallholder farms. [17] specified that among chemical, mechanical and hand weeded weed control in maize, the hand weeding at 20 and 40 DAP treatment was dominated due to lower net benefit and higher cost that varied, so it was an uneconomical treatment at the prevailing crop and herbicide prices.

3.7 Marginal Rate of Return

The 8l Lumax/ha gave higher net benefits of USD1366.23/ha and USD1834.29/ha as well as TVC of USD233.28/ha and USD260.22/ha in 2009 and 2010, respectively as against the net benefits of USD1356.25/ha and USD1830.91/ha as well as TVC of USD218.75/ha and USD245.84/ha recorded by the Hoe-weeded in 2009 and 2010, respectively. Applying 8l Lumax/ha over 8l Lumax/ha treatment gave a marginal rate of return (MRR) of 69% in 2009 and 24% in 2010 (Tables 3 and 4). The 8l Lumax/ha was, therefore, more profitable than the Hoe-weeded. Increasing Lumax dosage from 4l Lumax/ha to 6l Lumax/ha for the maize production gave an MRR of -70% in 2009 and -178% in 2010, which thereby made 6l Lumax/ha clearly unprofitable as compared to 4l Lumax/ha. Applying the 2l Lumax/ha over the Unweeded (control) gave an MRR of 371% in 2009 and 295% in 2010 while applying 4l Lumax/ha over the 2l Lumax/ha gave an MRR of 544% and 714% in 2009 and 2010, respectively. This indicates that for every USD100 invested, for example, in adopting 4l Lumax/ha over the 2l Lumax/ha, the farmer gets an additional gain of USD444 in 2009 and USD614 in 2010.

4. CONCLUSIONS

The 4l, 6l and 8l Lumax/ha and Hoe-weeded treatments provided higher grain yield of maize compared to the 2l Lumax/ha and Unweeded treatment in both years. The economic analysis, however, revealed the 4l Lumax/ha as the most economically viable option for weed control as it gave the highest net benefit. Application of 4l Lumax/ha showed dominance over other treatments and also gave better marginal rate of return than the other treatments and is therefore recommended for adoption across the transitional agro-ecological zone of Ghana and similar representative environments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not influenced by the producing company.

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