ID: 322

Sustainable Cowpea (*Vigna unguiculata* L.Walp) Production as Impacted by Integrated Weed Management Practices

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Abstract

Field trials were conducted over two consecutive growing seasons at the Research and Teaching farm of the Faculty of Agriculture, Bayero University Kano (Latitude 11° 58 N, Longitude 8° 25 E; altitude 458 m als). The efficacy of twelve different weed control treatments using various herbicides alone, in combination, or in addition to hoe weeding was evaluated on cowpea (var. IT99K-573-1-1) in a randomized complete block design (RCBD) with three replications. The treatments comprised of weedy check (control), hoe weeding at 3 & 6 weeks after sowing (WAS), metolachlor at 2.0 kg a.i.ha^{-1}, imazethapyr at 3.0 kg a.i.ha^{-1}, pendimethalin at 2.0 kg a.i. ha^{-1}, pendimethalin at 3.0 kg a.i. ha^{-1}, pendimethalin 1.0 + imazethapyr 1.0 kg a.i.ha^{-1}, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1}, imazethapyr 1.0 + pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor at 2.0 + SHW at 6 WAS, and pendimethalin at 2.0 + SHW at 6 WAS. Data were collected on cowpea growth, yield, and weed management parameters and were subjected to analysis of variance (ANOVA), and treatment means were compared using the Student Newman-Keuls test (SNK) at a 5% level of probability. Results indicated that weed control significantly ($p < 0.001$) influenced crop growth and yield. Herbicide treatments, particularly those involving pendimethalin, imazethapyr, and metolachlor, effectively suppressed weed growth, leading to increased plant height (101.9-147.9 cm), leaf area (44.87-47.93 cm^2), and number of leaves (113.17-122.03). Additionally, these treatments resulted in a higher number of pods (74.47-77.10) and seed yields (702.0-705.5 kg ha^{-1}) compared to the weedy check. Findings further revealed that the combination of herbicides with hoe weeding proved to be the most effective strategy, providing superior weed control and maximizing crop productivity. These findings highlight the importance of integrated weed management practices for sustainable cowpea production.

Key Words: *cowpea, integrated weed management, sustainable, weed control index*

Introduction

Cowpea (*Vigna unguiculata* L. Walp; Fabaceae) is a vital legume with widespread cultivation in Nigeria, playing a pivotal role in both subsistence farming and commercial agriculture. Its resilience to drought conditions and ability to thrive in nutrient-poor soils have established it as a valuable crop, particularly in regions facing these challenges (Ojo *et al*., 2018; Adediran *et al*., 2021). In recent years, the sustainable management of weeds in cowpea production systems has become a significant agricultural challenge in Nigeria.

The expected yield of the crop is considerably diminished by biotic and abiotic stresses, including edaphic factors, drought, cultivar selection, pest and disease infestations, with infestations by weeds being a significant contributor (Liliane and Charles, 2020; Anwar *et al*., 2021; Skendžić *et al.,* 2023). Uncontrolled weed infestation has been reported to cause a 90% reduction in the yield of cowpea (de Campos *et al*., 2023). Among the methods available for checkmating the weed infestation in cropping systems, chemical methods using preemergent herbicides are preferred due to efficiency, selectivity, and reduced drudgery. However, pre-emergence therapies alone are inadequate for preventing weed flushes through the rainy season, thus needing post-emergence therapy following pre-emergence control (Shittu, 2023; Shittu et al., Shittu and Bassey, 2023; Shittu and Lamarana, 2024).

The excessive use of herbicides has led to a myriad of environmental concerns, including water pollution, biodiversity loss, and the emergence of herbicide-resistant weeds (Nwafor *et al*., 2018; Nath *et al*., 2024). These adverse consequences necessitate the exploration of alternative weed control strategies. Addressing these challenges is crucial to ensuring the sustainability of cowpea production, particularly in the face of climate change and increasing global food demands. Integrated weed management (IWM) has emerged as a promising approach to address these challenges. IWM is a holistic strategy that combines various methods to control weeds while minimizing negative impacts on the environment and agricultural productivity. By integrating cultural, biological, and chemical control measures, IWM aims to create a more sustainable and resilient agricultural system (Olowe *et al*., 2020; Adebayo *et al*., 2022).

Additionally, combining cultural practices such as supplementary hoe weeding to broaden the spectrum efficacy of the preemergence herbicide will greatly enhances weed suppression and improves grain yield of cowpea. Thus, the study evaluated herbicide treatments and hoe weeding in Nigeria's cowpea farming system, aiming to improve weed control and crop yield using an integrated approach. The research aimed to determine the optimal combination of herbicides for sustainable weed management, influencing the development of more effective practices in a sustainable manner in the Sudano- Sahelian region of Nigeria.

Materials And Methods

The experiments were conducted during 2019 and 2020 rainy season at the Research and Teaching farm of the Faculty of Agriculture, Bayero University Kano (Latitude 11º 58 N, Longitude 8º 25 E; altitude 458 m als), in a randomized complete block design (RCBD) with three replicates. The soil at the experimental site was sandy loam with low accessible N (0.06 g kg^{-1}), low levels of P (4.87 g kg^{-1}) and medium levels of K (0.32 g kg^{-1}). The gross plot was 3 x 4.5 m (12 m^2) which is made up of six ridges (rows) while the net plot size was 1.5 m x 3 m (4.5 m^2) comprising the two inner rows with an alley of 0.5 m and 1.0 m between the plots and replications, respectively. The effectiveness of twelve different weed control treatments using various herbicides alone, in combination, or in addition to hoe weeding on cowpea (var. IT99K-573-1-1) was assessed. Every year, the crop was sown in the first week of July at a seed rate of 75 kg ha^{-1}, and treated two weeks later with NPK (15:15:15) and SSP (18%) at a rate of 20 kg N, 40 kg P_2O_5, and 20 kg K_2O ha^{-1}. The SSP was however applied during land preparation. Herbicidal treatments were applied as per treatment. The details of the treatments were as follows: weedy check (control), hoe weeding at 3 & 6 weeks after sowing (WAS), metolachlor at 2.0 kg a.i.ha^{-1}, imazethapyr at 3.0 kg a.i.ha^{-1}, pendimethalin at 2.0 kg a.i. ha^{-1}, pendimethalin at 3.0 kg a.i ha^{-1}, pendimethalin 1.0 + imazethapyr 1.0 kg a.i.ha^{-1}, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1}, imazethapyr 1.0 + pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor at 2.0 + SHW at 6 WAS, pendimethalin at 2.0 + SHW at 6 WAS. The herbicidal treatments either alone or in mixture were applied pre-emergence on the tested crop. Data were collected on weed attributes, crop growth and yield related characters which were subjected to analysis of variance (ANOVA) and treatment means were separated using Student Newman-Keuls-test (SNK) at 5% level of probability.

Results And Discussion

Crop Injury Scores and crop vigor

Table 1 presents the effect of weed control methods on crop injury score and crop vigor of cowpea during the 2019 and 2020 seasons and the combined. Results show that the weedy check and the plots that received hoe weeding at 3 and 6 WAS consistently resulted in the lower injury score compared to all other herbicidal treatments, either alone or integrated with hoe weeding at 6 WAS or tank mixture that resulted in slightly higher injury scores during the 2019 and 2020 rainy seasons and the combined. On the other hand, weedy check plots had significantly ($p < 0.001$) the lowest crop vigor scores compared to all other treatments across all seasons combined. The highly significant crop injury scores obtained between treatments, including the weedy check, are a positive finding. This aligns with research by Ribeiro Junior *et al.* (2018), who found that herbicides, when applied according to recommended rates and timings, generally cause minimal to no injury to cowpea plants. This suggests that the weed control methods tested in this study were safe for cowpea at the observed time (6 WAS), and it is highly selective to the crop. Similar findings were reported by Pedroso *et al.* (2020) and Correia and Carvalho (2021) in soybean and sweet potato, respectively.

Similarly, the clear distinction between treatments in terms of crop vigor is noteworthy. Weedy check plots consistently resulted in the lowest vigor scores compared to other treatments that resulted in statistically comparably higher vigor scores. This suggests that hoe weeding at 3 and 6 WAS and other herbicidal treatments provided the most effective weed control, allowing the cowpea plants to thrive with minimal competition for growth resources. The similar vigor scores observed with Imazethapyr, Pendimethalin, and some herbicide combinations compared to hoe weeding are promising. These findings align with studies by Anna Bárbara de *et al.* (2020) and Sinchana and Raj (2020), who reported that Imazethapyr and Pendimethalin effectively controlled weeds in cowpea, leading to improved crop growth and yield. Thus, these herbicidal treatment combinations may offer valuable alternatives to hoe weeding, particularly in situations where manual labor is limited.

Plant height and Number of Leaves

The impact of various weed control treatments on plant height and number of leaves of cowpea at 9 WAS across two growing seasons (2019 and 2020) and the combined is shown in Table 2. There was no significant ($P > 0.05$) variation in plant height during the 2019 and 2020 seasons. However, the weedy check plots resulted in the shortest plants, while all other treatments were not statistically comparable and taller when the seasons were combined. The observed significant differences in plant height between treatments highlighted the importance of weed control for cowpea growth. This corroborates the findings of Sinchana and Raj (2020), who reported that weed competition significantly reduced cowpea plant height compared to weed-free plots. The tallest plants were observed in the imazethapyr + pendimethalin

(1.0 + 1.0 kg a.i.ha^{-1} + SHW) treatment, followed by the pendimethalin (2.0 kg a.i.ha^{-1} + SHW) treatment. This suggests that these herbicide combinations, particularly when combined with SHW, were highly effective in controlling weeds, allowing cowpea plants to grow taller with less competition for growth resources. Conversely, the weedy check plots and plots treated solely with pre-emergence herbicide had statistically similar plant heights, indicating potential growth suppression due to unchecked weed competition that occurs later in the growing season. This finding agreed with those of Shittu (2023), Shittu and Bassey (2023), Shittu *et al.* (2023), and Shittu *et al.* (2024), who reported separately the inability of pre-emergence alone to provide season-long weed control in comparison with plots that received supplementary hoe weeding at 6 WAS or post-emergent herbicide, which cumulatively increase the efficacy of the weed control treatments in tomato, cowpea, and roselle and cucumber, respectively. Similarly, the weedy check plots had the lowest number of leaves ($P < 0.001$) when the years were combined, but plots treated with Pendimethalin at 2.0 kg a.i. ha^{-1} *fb* hoe weeding at 6 WAS recorded the highest number of leaves per plant, although at par with other treatments.

Table 1. Crop injury score and Crop vigor score of cowpeas as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Crop injury scores @ 6 WAS			Crop vigor scores @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	0.00d	0.00f	0.00d	5.33b	7.00b	6.17e
Hoe weeding at 3 and 6 WAS[1]	0.00d	0.00f	0.00d	9.00a	9.00a	9.00a
Metolachlor at 2.0 kg a.i.ha^{-1}	1.00ab	1.00bc	1.00c	8.33a	8.67a	8.50cd
Imazethapyr 3.0 kg a.i.ha^{-1}	1.33a	1.67ab	1.50abc	9.00a	9.00a	9.00ab
Pendimethalin 2.0 kg a.i.ha^{-1}	1.33a	2.33a	1.83ab	9.00a	9.00a	9.00ab
Pendimethalin 2.0 kg a.i.ha^{-1}	1.33a	2.33a	1.83a	8.67a	9.00a	8.84abc
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	1.33a	1.00bc	1.17bc	8.67a	9.00a	8.84abc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	1.00abc	1.00bc	1.00c	8.67a	8.67a	8.67abc
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	1.00abc	1.00bcd	1.00c	9.00a	9.00a	9.00a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	1.00abc	1.00b-e	1.00c	9.00a	9.00a	9.00a
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	1.00abc	1.00b-e	1.00c	9.00a	9.00a	9.00a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	1.33a	1.33b	1.33abc	9.00a	9.00a	9.00ab
P of F	0.001	<.001	<.001	<.001	0.006	<.001
SE±	0.2229	0.2546	0.1776	0.195	0.308	0.302

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding.

Table 2: Plant height and Number of leaves per plant of cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Plant height (cm) @ 9 WAS			Number of leaves plant^{-1} @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	84.8	86.8	85.8b	66.83	74.97	70.90e
Hoe weeding at 3 and 6 WAS[1]	115.0	116.8	115.9ab	103.93	106.00	104.97abc
Metolachlor at 2.0 kg a.i.ha^{-1}	138.0	118.5	117.1ab	89.87	92.00	90.93bcd
Imazethapyr 3.0 kg a.i.ha^{-1}	100.4	103.4	101.9ab	80.40	82.53	81.47cd
Pendimethalin 2.0 kg a.i.ha^{-1}	103.4	105.4	104.4ab	89.62	93.52	91.57bcd
Pendimethalin 2.0 kg a.i.ha^{-1}	103.3	108.1	105.7ab	89.97	92.87	91.42bcd
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	126.0	128.5	127.3ab	91.73	93.87	92.80bcd
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	115.3	128.5	117.5ab	95.73	98.40	97.07a-d
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	146.5	149.3	147.9a	113.67	112.67	113.17ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	139.3	105.4	141.1a	104.37	106.43	105.40abc
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	99.6	102.6	101.1ab	110.97	111.53	111.25ab
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	138.0	136.3	137.1a	121.20	122.87	122.03a
P of F	0.406	0.361	0.004	0.070	0.142	<.001
SE±	17.88	17.05	10.79	10.53	10.39	6.50

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Table 3. Leaf area and Laef area index of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Leaf area (cm^2) @ 9 WAS			Leaf area index @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	30.81f	34.00d	32.41e	1.05g	1.12c	1.09e
Hoe weeding at 3 and 6 WAS[1]	43.88ab	49.00a	45.94ab	1.85ab	2.24a	2.05a
Metolachlor at 2.0 kg a.i.ha^{-1}	36.07cde	37.45c	36.76d	1.47f	1.60b	1.53d
Imazethapyr 3.0 kg a.i.ha^{-1}	36.68bcd	39.57c	38.13cd	1.48f	1.65b	1.58cd
Pendimethalin 2.0 kg a.i.ha^{-1}	39.08abc	40.58bc	39.83cd	1.56cf	1.68b	1.60cd
Pendimethalin 2.0 kg a.i.ha^{-1}	40.28abc	41.22bc	40.75cd	1.60b-f	1.77ab	1.69bcd
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	41.10abc	44.00ab	42.55bc	1.79a-e	1.89ab	1.84abc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	44.42ab	45.32a	44.87ab	1.82a-d	2.00ab	1.91ab
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	45.68a	47.97a	46.83ab	1.81a-d	2.04ab	1.93ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	46.42a	47.00a	46.71ab	1.82abc	2.06ab	1.94ab
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	47.19a	48.33a	47.76a	1.90a	2.09ab	2.00a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	46.86a	48.00a	47.93a	1.92a	2.11ab	2.017a
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	1.768	1.114	1.208	0.061	0.109	0.074

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

The findings on the number of leaves suggest a potential positive influence of this treatment on leaf production. It's possible that hoe weeding minimizes herbicide-plant contact, which reduces herbicide phytotoxicity, ultimately leading to less stress on the cowpea plants and allowing for better growth. This is inline with the findings of Galon *et al*. (2021), who reported the increase in growth characters of canola and suppression of weed growth. The lack of a significant difference in the 2019 and 2020 seasons could be due to environmental factors or require a longer observation period beyond 9 WAS to detect variations in leaf production between treatments.

Leaf Area and Leaf Area Index

Table 3 presents the influence of various weed control treatments on leaf area and leaf area index (LAI) of cowpea at 9 WAS across two growing seasons (2019 and 2020) and combined. The result demonstrated that the weedy check plots had the smallest leaves overall. In both years, several treatments significantly ($P < 0.001$) resulted in the larger leaves, including a combination of herbicide and hoe weeding. Overall, the application of pendimethalin and metolachlor, each at 2.0 kg a.i.ha^{-1} + SHW at WAS, the combination of imazethapyr + pendimethalin (1.0 + 1.0 kg a.i.ha^{-1}) + SHW at 6 WAS, and metolachlor + pendimethalin (1.5 + 1.5 kg a.i.ha^{-1} + SHW) significantly resulted in larger leaves, which were at par with other treatments in the 2019 season. A similar trend of results was equally observed during the 2020 season as well as the combined effect. This suggests that the treatments with hoe weeding were particularly effective in controlling weeds, allowing cowpea plants to develop larger leaves with less competition for light and other growth resources. Conversely, the weedy check plots had the lowest leaf area, indicating limitations on leaf growth likely due to weed competition. This aligns with research by Enejoh *et al*. (2018), who found that uncontrolled weeds significantly reduced cowpea leaf area compared to weed-free plots.

Similar to leaf area, the leaf area index (LAI) results showed significant differences between treatments, mirroring the trends observed with leaf area. LAI is a critical parameter reflecting the canopy's light interception capacity, which directly influences photosynthesis. The lower LAI observed in the weedy check plots suggests reduced light interception and potentially lower photosynthetic potential, ultimately impacting plant growth and yield. The result is consistent with those of Saberali *et al*. (2016) and Bisikwa *et al.* (2021), who found that weed competition dramatically lowered cowpea LAI, which in turn led to lower biomass output. As such, crop canopy expansion and competitiveness for solar radiation and production of dry matter can be enhanced by suppression of weed growth within the crop canopy as emphasized by Evers and Bastiaans (2016). Similarly, Ibitoye *et al*. (2020) reported that employing integrated weed management strategies involving hand weeding or mechanical weeding combined with herbicides resulted in a greater leaf area and LAI in cowpea compared to herbicide application alone, which might be attributed to increased spectrum activity of the pre-emergence herbicides to smother the growth of the late-emerging weeds.

Number of pods per plant and Number of seeds per pod

The influence of various weed control treatments on cowpea yield-related characters is presented in Table 4. Results revealed that the application of 2 HW at 3 and 6 WAS, Pendimethalin and Metolachlor, each at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, significantly ($P < 0.001$) resulted in a higher number of pod plants, although at par with other treatments compared to the weedy check that had lower values in the 2019 and 2020 seasons and the combine. On the other hand, the application of metolachlor at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P < 0.001$) produced the highest number of seeds per pod, which was comparable with the rest of the treatments, although the weedy check resulted in a lower seed number per pod in both seasons and combined.

Table 4. Number of Pods per plant and Number of seeds per pod of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Number of pods plant^{-1}			Number of seeds pod^{-1}		
	2019	2020	Combined	2019	2020	Combined
Weedy check	42.47d	45.90d	44.18e	9.07b	10.13b	9.60c
Hoe weeding at 3 and 6 WAS[1]	76.37a	78.90a	77.63a	11.73ab	13.67ab	12.70ab
Metolachlor at 2.0 kg a.i.ha^{-1}	54.07c	56.20cd	55.13d	11.60ab	13.00ab	12.30ab
Imazethapyr 3.0 kg a.i.ha^{-1}	51.73c	53.77cde	52.75d	10.47ab	11.33ab	10.90bc
Pendimethalin 2.0 kg a.i.ha^{-1}	54.57c	57.37cd	55.97d	11.30ab	12.67ab	11.98ab
Pendimethalin 2.0 kg a.i.ha^{-1}	54.57c	52.47cd	53.78d	11.47ab	12.33ab	11.90ab
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	54.94c	56.37cd	55.65d	10.40ab	11.33ab	10.87bc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	62.10bc	64.43bc	63.27c	11.87a	13.00ab	12.43ab
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	68.40ab	70.10ab	69.25b	11.13ab	12.33ab	11.73ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	64.78b	67.78ab	66.28bc	11.53ab	13.00ab	12.27ab
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	74.47a	75.87a	75.17a	12.67a	14.33a	13.50a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	75.10a	77.10a	76.10a	11.40ab	12.67ab	12.03ab
P of F	<.001	<.001	<.001	0.023	0.061	<.001
SE±	2.475	2.671	1.715	0.552	0.767	0.508

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Table 5. Seed yield and 100 seed weight of cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Seed yield (kg ha^{-1})			Hundred seed weight (g)		
	2019	2020	Combined	2019	2020	Combined
Weedy check	301.3f	306.0f	303.7f	13.80c	14.95d	14.38b
Hoe weeding at 3 and 6 WAS[1]	699.3a	720.0a	709.7a	22.67a	20.97ab	21.82a
Metolachlor at 2.0 kg a.i.ha^{-1}	510.3e	525.7e	518.0e	18.50b	19.73abc	19.12a
Imazethapyr 3.0 kg a.i.ha^{-1}	520.0e	533.3ce	526.7e	18.47b	19.90ab	19.18a
Pendimethalin 2.0 kg a.i.ha^{-1}	560.3d	562.7cd	561.5d	18.97b	20.13ab	19.55a
Pendimethalin 2.0 kg a.i.ha^{-1}	564.7d	567.7c	566.2d	20.07b	21.47a	20.77a
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	586.3c	634.0b	610.2c	19.20b	20.33ab	19.77a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	593.7c	639.3b	616.5c	19.57b	20.83ab	20.20a
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	649.0b	699.0a	674.0b	19.47b	21.07ab	20.27a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	658.3b	698.7a	678.5ab	19.57b	20.83ab	20.20a
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	688.0a	716.0a	702.0ab	20.87ab	22.07a	21.47a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	693.3a	717.7a	705.5ab	21.47ab	22.60a	22.03a
P of F	<.001	<.001	<.001	<.001	0.050	<.001
SE±	6.07	9.99	8.74	0.661	1.304	0.731

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding.

Seed Yield and Seed Quality

Table 5 examines the influence of various weed control treatments on cowpea seed yield and hundred seed weight (g) across two years (2019 and 2020) and combined data. The weedy check had the lowest yield across all years. Similar to Table 4, treatments including hand weeding resulted in significantly ($P < 0.001$) higher yields compared to their non-SHW counterparts. For the 2020 rainy season, hoe weeding alone, as well as when integrated with other herbicide treatments, showed the highest seed yield per plot; however, during the 2019 rainy season, hoe weeding alone showed the highest yield and was not statistically different from plots treated with metolachlor and pendimethalin, both at 2.0 kg a.i. ha^{-1}, and Imazethapyr + Pendimethalin, each 1.0 kg a.i. ha^{-1} + SHW at 6 WAS, compared to other treatments that resulted in decreased seed yield, with the weedy check recording the lowest seed yield across both seasons and combined. The weedy check plots recorded the lowest 100 seed weights across all years and when the data was combined. The plots treated with hand weeding at 3 and 6 WAS recorded the highest seed weights and showed no statistical difference with plots treated with herbicide either alone or in combination with SHW at 6 WAS. The increase in seed yield and yield-related characters of cowpea achieved by the above treatments could be attributed to the efficacy of the second weeding applied to both hoe-weeded and herbicidal-treated plots, which is linked to its ability to suppress late-emerging weeds. This suppression enhances the plants' capacity to utilize available growth resources for photosynthate assimilation, ultimately increasing the production of dry matter allocated to sinks. This finding aligns with the reports of Adeyemi et al. (2019), Omovbude et al. (2020), Naeem et al. (2022), and Shittu et al. (2022), each of which documented the impact of supplementary hoe weeding on the effectiveness of pre-emergence herbicides in improving the productivity of maize, lowland rice, barley, and groundnut, respectively.

Weed characters

Table 6 reports the effects of different weed control treatments on weed cover score, weed index, and weed control index (WCI) of cowpea over two years (2019 and 2020) and the combined data. Weedy check plots consistently had the highest weed cover score and weed index and the lowest WCI across all years, indicating the most significant weed infestation. Performing hoe weeding at 3 and 6 WAS generally resulted in the lowest weed cover score and weed index, along with the highest WCI in both individual years and combined data. This suggests hoe weeding was very effective in controlling weeds. Several herbicide treatments showed promising results, particularly when combined with hoe weeding. These combinations often achieved weed control comparable to sole hoe weeding at 3 and 6 WAS. Among herbicides, a combination of Imazethapyr and Pendimethalin at 1.0 kg ha^{-1} each, or Metolachlor and Pendimethalin at 2.0 kg ha^{-1} each, were generally effective, especially when combined with hoe weeding, although they were at par with other treatments. This finding demonstrated the effectiveness of implementing additional hoe weeding at a later stage to manage late-emerging weeds and expand the range of herbicidal treatment as earlier reported by several scientists (Adeyemi *et al*., 2019; Omovbude *et al.,* 2020; Naeem *et al.,* 2022; and Shittu et al., 2022; Shittu and Lamarana, 2024).

Table 6. Weed covers score, Weed index and Weed control index of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Weed covers score			Weed index			Weed control index (%)		
	2019	2020	C	2019	2020	C	2019	2020	C
Weedy check	9.0a	8.00a	8.50a	53.57a	54.73a	54.15a	0.00h	0.00g	0.00i
Hoe weeding at 3 and 6 WAS[1]	1.67h	2.33cd	2.00h	0.00e	0.00g	0.00f	78.53a	78.53a	78.53a
Metolachlor at 2.0 kg a.i.ha^{-1}	6.33b	5.33b	5.83b	38.20b	39.20b	38.70b	46.50fg	47.67ef	47.08gh
Imazethapyr 3.0 kg a.i.ha^{-1}	5.67bc	5.00b	5.33bc	36.17b	36.53bc	36.35bc	50.73efg	50.73ef	50.73g
Pendimethalin 2.0 kg a.i.ha^{-1}	5.00cd	4.67b	4.83c	33.70b	34.30bc	34.00cd	58.50b-f	58.50b-e	58.50f
Pendimethalin 2.0 kg a.i.ha^{-1}	4.67d	4.67b	4.667cd	32.00b	30.60cd	30.47d	57.40def	57.40def	57.40f
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	4.67cd	3.33c	4.00de	32.00b	31.63bc	31.82d	60.00b-e	60.00b-e	60.00def
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	4.33d	3.33c	3.83e	30.33b	30.60cd	30.47d	60.00b-e	60.00b-e	60.00def
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	3.33e	2.67cd	3.00f	21.43cd	22.97def	22.20e	66.10a-d	66.10a-d	66.10b-e
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	3.33ef	2.67cd	3.00fg	22.80c	23.27e	23.03e	66.50a-d	66.50a-d	66.50b-d
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	2.67efg	2.000d	2.33fgh	22.73cd	23.17e	22.95e	72.47ab	72.47ab	72.47b
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	2.33e-h	2.00d	2.17fh	22.70cd	23.07de	22.88e	72.17abc	72.17abc	72.17abc
P of F	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.2611	0.2706	0.2412	1.880	1.963	1.199	3.182	3.199	1.976

C: Combined; Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student- Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Conclusion

This study investigated the impact of different weed control strategies on cowpea growth, yield, and weed control. The results demonstrated that weed control significantly influenced crop performance. Findings further revealed that herbicidal treatments, combined with hoe weeding, effectively control weeds, improving crop growth and yield, enhancing plant height, leaf area, light interception, and seed production. Therefore, integrated weed management involves combining pre-emergence herbicides with post-emergence hoe weeding, selecting appropriate herbicides based on weed spectrum, crop tolerance, and environmental factors, and implementing cultural practices for optimal control and increases the productivity of cowpea in the study area.

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