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Weed Suppressive Effects of Inter-Row Spacing and Weeding Frequency on Cowpea (*Vigna unguiculata* L. Walp) Yield in Calabar, Southeastern Nigeria

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ABSTRACT

Effective weed management is prerequisite for enhanced productivity of cowpea. Field experiments were conducted at the University of Calabar Teaching and Research Farm, during the 2014 and 2015 late cropping seasons, to evaluate the weed suppressive effects of inter-row spacing and weeding frequency on cowpea yield. Factorial combinations of three inter-row spacing regimes (60cm, 75cm, 90cm) and four weeding frequencies (no-weeding, weeding once, weeding twice and weeding thrice) were laid out in randomized complete block design, with three replications. Data collected on weed density (no m^{-2}), weed dry matter (gm^{-2}), number of branches plant^{-1}, yield parameters and grain yield (kgha^{-1}) were analyzed. Inter-row spacing at 60 cm tended to suppress weeds more than spacing at 90cm apart, and produced significantly ($P<0.05$) higher grain yield than wider inter-rows. Weeding frequency profoundly affected weed growth and cowpea performance. On the two-year average, weeding once, weeding twice and weeding thrice reduced weed density by 16.86%, 33.58%, 45.55%, and weed dry natter by 46.49%, 54.19%, 57.93% respectively, compared with the weedy treatment. No-weeding significantly ($P<0.05$) retarded all yield attributes of cowpea and depressed grain yield by 24.03% averaged over the years, compared with weeded plots. Weeding thrice maximized the number of branches plant^{-1} number of pods plant^{-1}, number of seeds pod^{-1} and grain yield. The combination of 60 cm inter-row spacing with weeding thrice, effectively suppressed weeds and produced consistently the highest grain yield (average 474.67 kgha^{-1}), and is therefore recommended for farmers growing Sampea 11 cowpea variety in the study area.

Key words: Weed density, Weed dry matter, Weed suppression, Cowpea grain yield

INTRODUCTION

Cowpea [*Vigna unguiculata* (L). Walp] is the most economically important African indigenous legume crop [1]. Because of its vast adaptability to various climatic conditions and cropping systems, cowpea plays vital nutritional roles as a food security crop and a cheap source of high quality plant protein for humans and animals across the tropics, especially Asia and Africa [2]. Nigeria has been the highest world producer of cowpea for over a decade, currently producing about 3 million tons per annum [3]. However, Nigeria is also the world largest consumer of cowpea with imports from neighboring countries such as Niger, Cameroon and Chad [4] to supplement production-demand deficits. Problems militating against cowpea production in Nigeria and elsewhere have been identified to include prevalent use of low yielding varieties by local farmers, persistent disease and pest attack, poor cultural practices and weed infestation [5,6]. Consequently, farmers' cowpea yields in Nigeria are generally low, averaging 0.10 - 1.55t ha^{-1} over a 45-year period across producing states [7], compared with potential yields of 1.9-2.6 t ha^{-1} from elite varieties [3]. Scientific research in cowpea improvement chiefly by the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria, has led to the development of several high yielding, disease-resistant and adapted cowpea varieties

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[3,8], which should herald increased productivity of cowpea across the agro-ecological zones of Nigeria and beyond. However, the potential gains from improved crop varieties can be confounded if weeds are not adequately controlled in the field. Weeds compete with the cowpea crop for above- and below- ground resources including sunlight, moisture and nutrients, thereby reducing its growth, yield and quality, as well as orchestrating attacks by pests and diseases, if not adequately and timely controlled [9]. Onuh *et al.* [10] reported that no-weeding resulted in depressed yield and yield parameters of cowpea. Yield reduction due to weeds in cowpea ranged from 12.7 to 90% [11-13], depending on the ecology, season and duration of competition. Studies have shown that increasing crop density through narrow row spacing can be viable tool for weed suppression in cowpea [2,14,15,16]. Nevertheless, row spacing, like other cultural methods, does not give full-season weed control, thus necessitating additional measures [16].

Manual weeding is the most predominant weed management practice in cowpea [9]. The frequency of hand weeding is influenced by factors such as life cycle of the crop, cropping system, predominant weeds present and the climatic condition of the area, amongst others. In Nigeria, most researches on weed control in cowpea have focused on the transition and dry savanna regions, where the crop is predominantly grown, and the findings show that hand weeding twice significantly reduced weed infestation and enhanced the growth and yield performance of cowpea [10,14,15]. However, cowpea production is moving south to the humid area [1,2], where aggravated pest infestation, especially weeds, limits the cultivation of legumes [6], thereby presenting a possible different weed management challenge to be investigated. The present study was undertaken to determine the impacts of different inter-row spacing regimes and weeding frequencies on weed suppression and the performance of cowpea in the Calabar coastal humid area, southeastern Nigeria.

MATERIALS AND METHODS

A two-year field experiment was conducted during the 2014 and 2015 late- (October-December) cropping seasons at the University of Calabar Teaching and Research Farm, Calabar, to assess the weed suppressive effects of inter-row spacing and weeding frequency on cowpea performance. Calabar is located between latitudes 04^0 45’ 30’’ and 05^0 08’30’’ N and longitudes 08^0 11’ 21’ and 08^0 27’ 00” E in the Southern rainforest agro-ecological zone of Nigeria. The area has ten months of rainfall (February-November), with annual rainfall often as high as 4,500 mm, mean temperature range of 22.6 – 30.8^0 C and relative humidity of 70-100 % [17]. Factorial combinations of three inter-row spacing regimes (60, 75 and 90cm) and 4 weeding frequencies [No-weeding, weeding once at 3 weeks after sowing (WAS), weeding twice at 3 and 5 WAS, weeding thrice at 3, 5 and 7 WAS] in randomized complete block design had three replications. Each of the 12 combined treatment plots measured 3m x 1.5m, separated by 1m and 0.5m paths between blocks and within blocks, respectively. Cowpea (SAMPEA 11) obtained from IITA, Ibadan, Nigeria, was sown three per stand at 25cm intra-row, across 60, 75 and 90 cm inter-rows. The plants were thinned to two per hill at 2 WAS, giving populations of 133, 333; 106,666 and 88,888 plants ha^{-1}, respectively. Weed assessment was done at 5 and 8 WAS using a 50cm x 50cm quadrat placed randomly twice on each plot [18]. The enclosed weeds were harvested, counted, pooled over the sampling periods and expressed on m^2 basis for the weed density. The harvested weeds were oven dried at 70 ^{0}C to a constant weight to determine the weed dry matter, converted to m^2 area [19]. The predominant weed species found during the field study include *Cyperus esculentus* L., *Cyperus rotundus* L, *Kyllinga squamulata* Thonn. ex Vahl, *Cleome rutidosperma* DC., *Mucuna prurient s*(L.) DC*.*, *Commelina benghalensis* L., *Centrosema pubesens* Benth., *Mimosa pudica* L. and *Panicum maximum* Jacq. Crop performance was assessed using mean values from six randomly tagged plants within the middle rows. The number of branches $plant^{-1}$ was determined by counting the number of primary reproductive branches at 8 WAS. Pod length (cm), number of pods $plant^{-1}$, number of seeds pod^{-1} and grain yield ($kgha^{-1}$) were determined at crop harvest. Data collected were subjected to analysis of variance (ANOVA) using

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Genstat statistical software. Means were compared using the Fisher's Protected Least Significant Difference at 5% probability level.

RESULTS

Weed Density

Lowest weed density was obtained at the narrowest (60cm) inter-row spacing, statistically similar (P> 0.05) to 75cm spacing apart, while the widest inter-row spacing (90cm) had significantly (P<0.05) the highest weed density in both years (Table 1). Plots weeded thrice produced significantly (P<0.05) the lowest weed density compared with other weeding frequencies except weeding twice in 2014, whereas the no-weeding treatment produced the highest weed density across the years. On the two-year average, weeding once, weeding twice and weeding thrice reduced weed density by 16.86, 33.58 and 45.55% compared with no-weeding. Statistically similar (P>0.05) weed density was obtained at 60cm and 75cm inter-rows with weeding twice or thrice, and at 90cm inter-row with weeding thrice, which were significantly lower (P<0.05) than other treatment combinations. Spacing cowpea at 90cm apart combined with no-weeding produced significantly (P<0.05) the highest weed density values on the two-year average.

Weed Dry Matter

The main and interactive effects of inter-row spacing and weeding frequency on weed dry matter are presented in Table 1. Spacing at 90cm apart produced the highest weed dry matter, statistically similar (P>0.05) to values for 75cm and 60cm inter-rows in 2014 and 2015, respectively. No statistical differences in weed dry matter were found among spacing regimes on the two-year average. Weed dry matter in the no-weeding treatment was significantly higher (P<0.05) than that of the weeded plots in both years except plots weeded once in 2014. Average over years, weeding once, weeding twice and weeding thrice reduced weed dry matter by 46.49%, 54.19% and 57.73% respectively, compared with the weedy plots. The interaction showed that highest weed dry matter reduction was attained in plots with cowpea spaced at 75cm apart and weeded three times, followed without statistical difference by 60cm, 75cm and 90cm inter-rows with weeding once, weeding twice and weeding thrice, respectively over the two- year period.

Table 1: Main and interactive effects of inter-row spacing and weeding frequency on weed density (m^2) and weed dry matter (g m^{-2}) in cowpea field

Treatments	Weed density (no m^{-2})			Weed dry matter (g m^{-2})		
Inter-row spacing	**2014**	**2015**	**Mean**	**2014**	**2015**	**Mean**
60 cm	74.70	77.30	76.00	28.13	25.97	27.05
75 cm	76.20	79.50	77.85	31.23	24.19	27.71
90 cm	95.50	86.30	90.90	32.70	27.07	29.89
LSD (0.05)	7.20	7.00	7.62	4.27	2.82	3.56(ns)
Weeding frequency						
No-weeding	87.80	126.90	107.35	39.69	53.82	46.76
Weeding once	90.50	88.00	89.25	34.79	15.26	25.02
Weeding twice	77.30	65.30	71.30	25.17	17.68	21.42
Weeding thrice	72.90	44.00	58.45	23.12	16.21	19.67
LSD (0.05)	8.32	8.09	8.80	4.93	3.25	4.11

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Inter-row spacing x weeding frequency						
60 cm x No-weeding	82.70	121.30	98.30	32.90	48.40	40.65
60 cm x Weeding once	82.70	78.70	80.00	26.58	16.80	21.69
60 cm x Weeding twice	67.30	60.00	65.30	23.78	20.20	21.99
60 cm x Weeding thrice	72.00	49.30	60.30	29.26	18.46	23.86
75 cm x No-weeding	82.70	123.30	97.70	44.58	53.00	48.79
75 cm x Weeding once	82.70	90.00	86.30	39.06	15.12	27.09
75 cm x Weeding twice	67.30	66.00	65.70	22.72	14.98	18.85
75 cm x Weeding thrice	72.00	38.71	55.30	18.58	13.66	16.12
90 cm x No-weeding	105.30	136.00	120.70	41.58	60.06	50.82
90 cm x Weeding once	107.30	95.30	101.30	38.72	13.86	26.29
90 cm x 25cm x Weeding twice	94.00	70.00	81.90	29.00	17.86	23.43
90 cm x 25cm x weeding thrice	75.30	44.00	59.70	21.52	16.52	19.02
LSD (0.05)	14.41	14.01	15.24	8.54	5.64	7.12
CV (%)	10.40	10.20	11.10	16.40	12.90	14.8

Number of Branches per Plant

Only in 2014 was the effect of inter-row spacing significant on number of branches per plant with the 90cm spacing having statistically (P<0.05) higher values than the narrower regimes (Table 2). The number of branches per plant progressively increased as the wedding frequency increased from zero to three in both years. No-weeding retarded number branches per plant by 15.82 - 44.81% relative to weeded treatments. On the other hand, weeding once, weeding twice and weeding thrice enhanced the number of branches per plant by 18.79%, 20.92% and 81.21% in that order over the weedy treatment. The interaction showed that plots weeded three times produced significantly (P<0.05) the highest number of branches per plant, while the least values were generally obtained from no-weeding treatments across the three inter-row spacing regimes.

Table 2: Number of branches per cowpea plant as influenced by inter-row spacing and weeding frequency in 2014 and 2015 cropping seasons

Treatments	Number of Branches plant^{-1}		
Inter-row spacing	**2014**	**2015**	Mean
60 cm	2.78	4.52	3.65
75 cm	2.56	4.59	3.58
90 cm	3.15	4.43	3.79
LSD (0.05)	0.32	0.47 (ns)	0.38 (ns)
Weeding frequency			
No-weeding	2.68	2.96	2.82
Weeding once	2.96	3.74	3.35
Weeding twice	2.06	4.75	3.41
Weeding thrice	3.61	6.60	5.11
LSD(0.05)	0.37	0.54	0.44
Inter-row spacing x Weeding frequency			

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60 cm x No-weeding	2.73	3.03f	2.88
60 cm x Weeding once	3.14b	3.96	3.55
60 cm x Weeding twice	1.50	4.80	3.15
60 cm x Weeding thrice	3.75	6.30	5.03
75 cm x No-weeding	2.41	3.03	2.72
75 cm x Weeding once	1.91	3.80	2.86
75 cm x Weeding twice	2.10	5.00	3.55
75 cm x Weeding thrice	3.83	6.53	5.18
90 cm x No-weeding	2.91	2.83	2.87
90 cm x Weeding once	3.83	3.46	3.65
90 cm x Weeding twice	2.58	4.46b	3.52
90 cm x Weeding thrice	3.2c	6.96	5.11
LSD (0.05)	0.63	0.93	0.76
CV (%)	13.2	12.2	12.2

Yield components and grain yield (kgha^{-1})

Tables 3 and 4 show the main and interactive effects of inter-row spacing and weeding frequency on yield parameters and grain yield of cowpea. Inter-row spacing at 60cm and 90cm significantly (P<0.05) increased pod length compared with 75cm inter-row plots in 2015 and on the two-year average (Table 3). With respect to weeding frequency, the longest pods were obtained from plots weeded two times, followed without statistical difference by plots weeded three times, while no-weeding produced the shortest pods on the two-year average. Generally, weeding enhanced pod length by 25.76-35.36% compared to no weeding. Interactively, pods were shortest in plots with no-weeding across the spacing regimes. The number of pods per plant was not significantly affected (P>0.05) by inter-row spacing, but by weeding frequency (Table 3). Weeding once or twice and weeding thrice gave significantly (P<0.05) the highest number of pods per plant in 2014 and 2015 respectively, whereas the no-weeding treatment had consistently the least values. Averaged over the years, weeding once, weeding twice and weeding thrice increased the number of pods per plant by 66.00, 78.13 and 200.78% respectively compared with no-weeding. Conversely, no-weeding depressed the number of pods per plant by 40.05, 43.86 and 66.75% respectively, relative to weeding once, weeding twice and weeding thrice, in that order. On the whole, spacing at 90cm combined with weeding thrice produced significantly the highest number of pods per plant, followed with statistical similarity by spacing at 60cm apart with weeding thrice.

Table 3: Main and interactive effects of inter-row spacing (cm) and weeding frequency on pod length (cm) and number of pods per plant of cowpea

Treatments	Pod length (cm)			Number of Pods Plant^{-1}		
Inter-row spacing	**2014**	**2015**	**Mean**	**2014**	**2015**	**Mean**
60 cm	12.89	12.65	12.78	4.23	4.07	4.15
75 cm	12.19	12.04	12.12	4.57	4.17	4.37
90 cm	12.65	13.14	12.90	4.43	4.25	4.35
LSD (0.05)	0.61	0.53	0.45	0.44 (ns)	0.37 (ns)	0.41ns
Weeding frequency						
No-weeding	10.43	9.98	10.21	3.12	1.99	2.56
Weeding once	12.71	12.97	12.84	5.17	3.35	4.27
Weeding twice	13.55	14.08	13.82	5.05	4.07	4.56

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Weeding thrice	13.31	13.42	13.51	4.28	7.25	7.70
LSD (0.05)	0.71	0.61	0.52	0.51	0.43	0.47
Inter-row spacing x Weeding frequency						
60 cm x No-weeding	11.56	10.33	10.95	2.45	1.80	2.13
60 cm x Weeding once	13.06	13.65	13.36	4.78	4.37	4.58
60 cm x Weeding twice	11.88	12.04	11.96	4.67	3.70	4.19
60 cm x Weeding thrice	15.06	14.60	14.83	5.01	6.40	5.71
75 cm x No-weeding	9.70	10.41	10.06	3.86	2.20	3.03
75 cm x Weeding once	10.88	11.25	11.07	5.41	2.87	4.14
75 cm x Weeding twice	15.17	14.50	14.84	5.75	4.13	4.94
75 cm x Weeding thrice	13.01	12.00	12.51	3.25	7.47	5.36
90 cm x No-weeding	10.03	9.21	9.62	3.00	1.97	2.49
90 cm x Weeding once	14.20	14.00	14.10	5.33	2.80	4.07
90 cm x Weeding twice	13.61	15.70	14.66	4.75	4.37	4.56
90 cm x Weeding thrice	12.75	13.65	13.20	4.58	7.87	6.23
LSD (0.05)	1.23	1.06	0.91	0.89	0.74	0.81
CV (%)	5.8	5.0	4.2	11.90	10.40	11.2

Spacing at 90 cm apart significantly enhanced the number of seeds per pod in 2014 and on the two-year average, compared with narrower spacing intervals (Table 4). Increasing weeding frequency from zero to three times progressively enhance the number of seeds per pod each year. On the two-year mean, weeding once, weeding twice and weeding thrice increased seeds per pod by 48.61, 110.58 and 173.05%, respectively compared with no-weeding. When treatments were combined and averaged over the years, similar and statistically ($P<0.05$) the highest number of seeds per pod was obtained from plots weeded thrice across the three spacing regimes, while the least values were recorded in the no-weeding treatments across spacing regimes.

Table 4: Number of seeds per pod and grain yield (kgha^{-1}) of cowpea as influenced by inter-row spacing and weeding frequency

Treatment	Number of Seeds pod^{-1}			Grain yield (kg ha^{-1})		
Inter-row spacing	**2014**	**2015**	**Mean**	**2014**	**2015**	**Mean**
60 cm	7.09	7.09	7.08	359.10	316.80	337.95
75 cm	6.97	7.04	7.04	316.20	264.00	290.10
90cm	7.66	7.66	7.66	350.33	218.20	284.27
LSD (0.05)	0.67	0.69ns	0.44	24.40	25.52	25.25
Weeding frequency						
No-weeding	5.00	2.94	3.97	330.20	161.40	245.80
Weeding once	7.66	4.13	5.90	322.00	210.80	266.40
Weeding twice	7.94	8.77	8.36	318.10	308.20	313.15
Weeding thrice	8.41	13.27	10.84	397.10	385.10	391.10
LSD (0.05)	0.78	0.80	0.51	28.17	29.47	29.15
Inter-row spacing x Weeding frequency						
60 cm x No-weeding	4.17	2.80	3.49	276.33	189.55	232.94

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60 cm x Weeding once	7.33	4.26	5.80	352.67	250.66	301.67
60 cm x Weeding twice	7.75	9.30	8.53	320.60	364.44	342.50
60 cm x Weeding thrice	9.10	11.96	10.53	486.67	462.66	474.67
75 cm x No-weeding	6.00	3.00	4.50	330.33	159.46	244.90
75 cm x Weeding once	6.33	3.73	5.03	340.66	213.87	277.27
75 cm x Weeding twice	7.83	8.00	7.92	337.67	305.24	321.46
75 cm x Weeding thrice	7.73	13.66	10.70	256.33	377.59	316.96
90 cm x No-weeding	4.83	3.03	3.93	384.00	135.11	259.56
90 cm x Weeding once	9.16	4.40	6.78	272.69	167.92	220.30
90 cm x Weeding twice	8.23	9.03	8.63	296.00	254.80	275.40
90 cm x Weeding thrice	8.40	14.1	11.28	448.67	315.11	381.89
LSD (0.05)	1.34	1.38	0.89	48.80	51.05	50.50
CV (%)	11.00	11.20	7.20	8.4	11.3	9.80

Cowpea grain yield was highest at 60 cm inter-row spacing, statistically similar to values from plots spaced at 90cm in 2014 (Table 4). Averaged over both years, grain yield was highest at the narrowest (60cm) inter-row spacing (337.95 $kgha^{-1}$) indicating 16.49 and 18.88 % yield advantage over the wider 75cm and 90cm spacing regimes which produced 290.10 kg ha^{-1} and 284.27 grain yields, respectively. Weeding thrice produced significantly ($P<0.05$) the highest grain yield, while the no-weeding resulted in a mean grain yield reduction of 24.03 % over the years, compared with weeded plots. When plots were weeded once, twice and thrice, cowpea grain yield was enhanced by 8.38, 27.4 and 59.11 %, respectively (average 31.63 %) relative to no-weeding over the period of study. Weeding thrice further increased cowpea grain yield by 31.88 and 19.98 % compared with weeding once and weeding twice, averaged over the two years. The combination of 60 cm inter-row spacing with weeding thrice gave consistently the highest grain yield with an average of (474.67 $kgha^{-1}$), while the no-weeding treatments at the various spacing regimes produced the least grain yields.

DISCUSSION

The significant reductions in weed density in both years and weed dry matter in 2014 obtained at the narrowest inter-row (60cm), compared to the widest inter-row (90cm) suggests superiority of the former over the latter in weed suppression. At 60cm inter-rows, plant population was 50% higher, which reduced niches available for weeds to thrive in, and possibly ensured quicker canopy closure and better crop competition with weeds, compared to 90cm spacing apart. The overall similarity in the number of branches per plant (two-year average) and the number of pods per plant across the spacing regimes indicates no adverse intra-specific competition at the closest row spacing (60cm). Consequently, the greater plant population in the 60cm inter-row treatment translated to higher grain yield per hectare. This result agrees with previous research findings that, narrow inter-row spacing controlled weeds better [2] and enhanced cowpea yield [2,5].

Weeding frequency profoundly affected weed growth, yield attributes and grain yield of cowpea. Expectedly, mean weed density and weed biomass were statistically highest in the weedy treatment, due to the uninterrupted utilization of growth resources over time by weeds in those plots. The detrimental effects of uncontrolled weed growth on the cowpea crop were illustrated by the significant reductions in the number of branches per plant, pod length, number of pods per plant, number of seeds per pod and ultimately grain yield, obtained from the no-weeding treatment. This result is consistent with the findings of other researchers in Nigeria and elsewhere [10,11], who reported decreases in growth; yield attributes and grain yield of cowpea due to weed interference. On the other hand, full-season weed competition did not lead to total crop failure in this study; rather, appreciable

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yields were obtained from the weedy plots, thereby confirming reports that the cowpea crop is a strong competitor with weeds [20], because of its smothering ability [21]. At least hand weeding twice was necessary to enhance cowpea yield above the weedy treatment values. This is the point from which weed density and weed dry matter were consistently lower in the weeded plots relative to the weedy treatment. Furthermore, best cowpea growth and yield performance was recorded in the treatment weeded thrice, indicating its superiority over less frequent weeding regimes in the study area. Whereas, two timely hand weeding operations significantly controlled weeds and improved cowpea performance in the transitional and drier savanna regions of Nigeria [10,15], the observed enhancement in weed suppression and cowpea yield at three times weeding in this study indicates that the cowpea crop benefited significantly form an additional (3rd) hand weeding in the area of study. The need for more regular hand weeding in the Calabar area as revealed in this study, probably arises from the nearly all-year-round high intensity rainfall of the coastal town [17], thus orchestrating rapid weed resurgence and growth in crop fields [22]. It has been emphasized that a third weeding just before flowering of cowpea could be necessitated by field conditions [3].

The interaction results reveal that significant weed suppression was attained by combining narrow inter-row (60cm) spacing of cowpea with hand weeding twice, whereas hand weeding up to three times was required to attain similar effectiveness in weed suppression when cowpea rows were 90cm apart. Although weeding thrice resulted in similar weed density and weed dry matter reduction, and similarly enhanced most yield attributes of cowpea across spacing regimes, the integration of 60cm inter-row spacing with weeding thrice significantly maximized grain yield. Therefore, farmers in the Calabar humid area can integrate 60cm inter-row spacing with hand weeding thrice for effective weed suppression and enhanced cowpea grain yield.

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AUTHORS' CONTRIBUTIONS

Dr. Francis Aniezi Nwagwu conceived the research and wrote the manuscript. Miss Udoidiok, Idorenyin Marshall conducted the field work and analyzed the data in 2014. Ms. Udo, Utibe Sunday conducted the field work and collected data in 2015. Dr. Okore, Ikokwu Kalu analyzed the data in 2015 and read the manuscript with critical inputs.

CONFLICT OF INTEREST

None

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