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Effects of early and late post-emergence application of imazaquin on the control of *Euphorbia heterophylla* weed in cowpea

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Abstract
Cowpea in its initial growth phase suffers from weed interference. Use of herbicide is becoming widespread in cowpea production. *Euphorbia heterophylla* Linn has defied most herbicides; metolachlor, pendimethalin and metobromuron, commonly used in cowpea do not control the weed. Imazaquin and some herbicides have shown some level of control of the weed in late application. There used to be some the potential loss in herbicide efficacy when applications are delayed. The objective of this study is to assess the effectiveness of early and late post - emergence application of imazaquin in the control of wild poinsettia in cowpea. In the combined analysis, use of imazaquin at 0.125 and 0.25 kg a.i./ha resulted in similar cowpea height, pod dry weight (10.0 and 12.1g/pot), numbers of leaves (13.8 and 15.3) and branches per plant (1.8 and 2.6) respectively, and number of days to 50% flowering. Weed control efficacy, weed population and weed dry weight per pot were similar irrespective of the two rates of application. Early post-emergence application of imazaquin resulted in greater number of leaves (20.3 and 8.8) and number of branches per cowpea plant (3.42 and 0.92); better weed control efficacy (73.3 and 24.9 %), lower weed population and lower weed dry weight as well as greater pod dry weight per pot (15.1 and 7.1 g/pot) respectively. Early pre-emergence application at 10 days after sowing of imazaquin at 0.125 kg a.i./ha is therefore recommended for the control *Euphorbia heterophylla* in cowpea plots.

Keywords: wild poinsettia, imazaquin, herbicide application, cowpea, weed control

Introduction
Nigeria has the biggest consumption and production of cowpea (*Vigna unguiculata* (L) Walp) with annual production of 2.4 million tonnes (Osipitan, 2017) [7]. In locations where subsistence farming is mostly practiced where cowpea is mainly grown, it serves as a source of concentrated protein which is cheaper than fish, poultry, meat, or dairy products and combines properly with cereal grains in the human diet **(**Hall, 2012) [4]. Cowpeas are very vital as rotation crop with cereals. They usually improve the soil fertility with respect to phosphate and nitrogen, thereby benefiting later cereal crops **(**Hall, 2012) [4]. When cowpea is in its initial growth phase, it suffers from weed interference particularly before ground cover. Yield losses in cowpea may be up to 76% depending on weed management practices, environment and cowpea cultivar (Osipitan, 2017) [7].
Use of herbicide is becoming very popular in crop production. One of the most serious weeds of cowpea which has defied most herbicides is wild poinsettia. This broadleaved annual weed is common in most farms in the Delta State, Nigeria. The herbicides that are commonly used in cowpea production such as metolachlor, pendimethalin and metobromuron control the main weeds in cowpea effectively while they do not control *Euphobia heterophylla* (Akobundu, 1979 and Fadayomi, 1979) [1, 3]. In worm climates, *E. heterophylla* is found in pastures, vegetables, cultivated crops and wastelands; it is known to be a particularly troublesome serious weed of cowpea and soybean among other crops (Wilson, 1981). *Euphorbia heterophylla* is an invasive weed and it is very important economically in crop production (Machado *et al.*, 2020) [6]. Understanding the potential loss in herbicide efficacy when applications are delayed is important to prevent weed control failures (Eure *et al.*, 2013) [2]. The objective of this study is to assess the effectiveness of the application of imazaquin in the control of wild poinsettia and determine which of the two post emergence applications is better.

Materials and Methods
Pot experiment was conducted to assess the effects of time of post-emergence application as well as the concentration of imazaquin on the effectiveness of wild poinsettia control in cowpea. The experiment lasted for eighty one days; it was set up on the 15th of August, 2017 and terminated on the 4th of November, 2017.
Eighteen black polythene bags with four drainage holes of 36 cm x 23 cm dimension were filled each with approximately 15 kg of top soil obtained from the Oil Palm Plantation located in the Delta Investment Limited, Delta State University, Asaba Campus, Nigeria. The pots were arranged on a level ground in the green house premises of the Department of Agronomy, Delta State University, Asaba Campus, Nigeria. The pots were watered thoroughly until water started draining freely from the four drainage holes in the pots. Cowpea seeds of TVx 3236 variety were planted at approximately 1.5 cm depth and four seeds per pot, wild poinsettia seeds were planted at the rate of about 100 seeds per pot at a depth of approximately 1 cm. only cowpea seeds were planted in weed free control plots. No thinning was carried out on wild poinsettia seedlings while cowpeas were thinned to two seedlings per pot at twelve days after sowing. Imazaquin [2[4, 5-dihydro-4-methyl-4(1-methylethyl)-5-oxo-1H-imidazol-2-yl] 3-quinoline carboxylic acid] was

used at the rate of 0.125 and 0.250 kg a. i. /ha, each applied at 10 Days after Sowing (DAS) and 30 DAS. The imazaquin herbicide was applied using CP knapsack sprayer which was fitted with polijet nozzle calibrated in a 2 m x 4 m marked out area to deliver 260 l /ha spray volume. Hoagland's solution was applied three times at ten days intervals beginning from the 31st of August, 2017 at 15, 25 and 35 days after sowing; the rate of application was 200 ml per pot. The application was made directly to the soil surface, to avoid contact with foliage of cowpea and wild poinsettia. Bi-weekly application of Cypermethrin was carried out three times at 28, 42 and 56 days after sowing to control insect pests at the rate of one ml per litre of water. Data collected on cowpea were: days to flowering, stem height, number of leaves and number of branches per plant, leaf and pod dry weight. Population and dry weight of wild poinsettia were also collected. The wild poinsettia in each pot was collected, oven dried to constant weight at 70 ^{0}C. Citizen Electronic Balance with capacity of 2 000 g maximum was used to measure the weight of the wild poinsettia.

The four treatments in the study were imazaquin at 0.125 kg a. i. /ha applied at 10 DAS, imazaquin at 0.125 kg a. i. /ha applied at 30 DAS, imazaquin at 0.250 kg a. i. /ha applied at 10 DAS and imazaquin at 0.250 kg a. i. /ha applied at 30 DAS. Two controls were involved: un-weeded and weed free controls. The weed free conditions were maintained by hand pulling all weeds as soon as they emerged. The treatments were laid out in a randomized complete block design and replicated trice. Before analysis, data concerning wild poinsettia population and its biomass per pot were transformed by means of square root scale of $\sqrt{x+0.5}$ as suggested by Little and Hills (1978) [5]. Treatments data were subjected to analysis of variance and treatment means separated using Duncan's multiple range tests at 5 % level of probability.

Results

Cowpea pod dry weight

Early post-emergence application (10 DAS) of imazaquin resulted in the production of pod dry weight similar to what was produced in weed free pots. Delay in the application of imazaquin to 30 DAS resulted in less cowpea pods dry weight than the weed free pots

Days to 50 % flowering

Application of imazaquin significantly affected days to 50 % flowering in cowpea. In the study, 50 % flowering in cowpea occurred between 48.7 and 57.0 days after planting. Cowpea plants grown in pots that received early post-emergence application (at 10 DAS) of imazaquin at 0.125 and 0.250 kg a.i. /ha had significantly earlier flowering than the ones grown in weedy pots and the ones that received higher concentration of imazaquin and sprayed at 30 DAS. Cowpea plants all the herbicide treated pots and the weed free control pots had cowpea which flowered significantly earlier than the ones grown in weedy pots.

Weed dry weight

Concentration had no significant effect when 0.125 and 0.250 kg a.i./ha of imazaquin were sprayed at 10 DAS, they had similar weed dry weight of 16.7 and 14.4 g/pot, respectively. But when the time of herbicide application was delayed until 30 DAS, the higher concentration had significantly lower (31.3g/pot) weed dry weight than the one with the lower herbicide concentration (51.5 g/pot). Each of the herbicide treated pots had significantly lower weed dry weight than the un-weeded pots.

Weed control efficacy

Stage of post-emergence application had significant effect on weed control efficacy. The high and low concentrations of imazaquin resulted in similar weed control efficacy when they were sprayed at 10 DAS. Application of the herbicide at 30 DAS resulted in the higher concentration of the herbicide giving a better (58.0 %) weed control efficacy than the lower concentration (43.6 %).

Cowpea leaf dry weight

Leaf dry weight ranged from 1.9 g/pot in pots that received higher rate of imazaquin sprayed at 30 DAS to 9.5 g/pot in weed free pots. Pots that received imazaquin at lower rate had 7.1 g/pot of cowpea leaf dry weight which was similar to 9.5 g/pot produced by cowpea in weed free pots; these were significantly greater than what was produced in any of the other treatments which ranged from 1.9 to 3.7 g/pot.

Comparison of early and late post-emergence application of imazaquin

Post-emergence application of imazaquin at ten and thirty days after sowing resulted in similar cowpea height and number of days to 50% cowpea flowering. The cowpea plants in imazaquin treatments were similar in height of 243.8 cm while the days to 50% flowering ranged from 49.2 to 53.0 in early and late post-emergence application of imazaquin treatments, respectively. Early post-emergence application of imazaquin resulted in greater number of leaves and number of branches per plant (Fig. 3). Similarly, applications at 10 days resulted in better WCE, lower weed population and lower weed dry weight as well as greater cowpea leaf dry weight (Table 4) and greater cowpea pod dry weight per pot than application at 30 days (Figure 2).

Table 1: Effects of time of pre-emergence application of imazaquin in cowpea pots on the growth attributes of cowpea

Imazaquin treatment	Cowpea height (cm)	No. of leaves/ plant	No. of branches/ plant	Days to 50% flowering
EL	234.3	19.0 b	3.5 ab	48.7 c
EH	253.3	21.5 ab	3.3 b	49.7 bc
LL	259.3	8.5 c	0.0 d	51.3 bc
LH	228.3	9.2 c	1.8 c	54.7 ab
Free	216.0	23.5 a	4.3 a	50.3 bc
Weedy	241.6	6.3 c	0.0 d	57.0 a
SE ±	Ns	1.552	0.408	2.152

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
DAS = Days After Sowing, EL= 0.125 kg a.i./ha applied 10 DAS, HE= 0.25 kg a.i./ha applied 10 DAS, LL= 0.125 kg a.i./ha applied 30 DAS, LH= 0.25 kg a.i./ha applied 30 DAS, FREE = Weed free control and Weedy = Un- weeded control

Table 2: Effects of time of pre-emergence application of imazaquin on the control of wild poinsettia on wild poinsettia and cowpea dry weight

Treatment	Weed control (%)	Weed dry wt. (g/pot)	Weed population	Cowpea Leaf dry wt. (g/pot)
EL	70.3 b	16.2 c	62.7 b	7.9 ab
EH	76.2 b	12.8 c	51.0 b	10.4 a
LL	8.0 d	47.2 a	86.3 a	3.7 c
LH	41.8 c	31.4 b	90.7 a	5.4 bc
Free	100.0 a	0.0 d	0.0 c	10.1 a
Weedy	0.0 d	54.6 a	99.0 a	3.1 c
SE ±	7.630	4.510	5.774	1.692

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
DAS = Days After Sowing, EL= 0.125 kg a.i./ha applied 10 DAS, HE= 0.25 kg a.i./ha applied 10 DAS, LL= 0.125 kg a.i./ha applied 30 DAS, LH= 0.25 kg a.i./ha applied 30 DAS, FREE = Weed free control and Weedy = Un- weeded control

Table 3: Effect of imazaquin concentration on cowpea pod dry weight

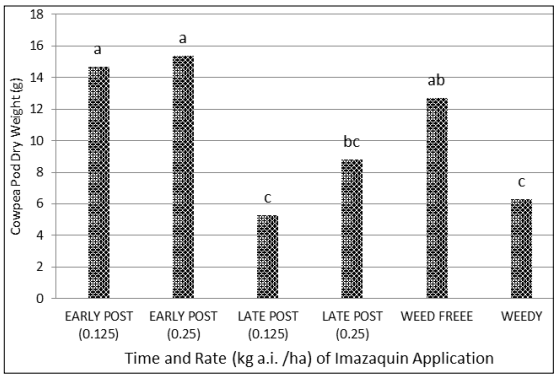
	Cowpea height (cm)	No. of leaves/ plant	No. of branches/ plant	Days to 50% flowering
Early-post emergence	243.8	20.3 b	3.4 a	49.2 b
Late-post emergence	243.8	8.8 c	0.9 b	53.0 ab
Free	216.0	23.5 a	4.3 a	50.3 b
Weedy	241.6	6.3 c	0.0 b	57.0 a
SE ±	Ns	1.552	0.408	2.152

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
Ns= not significant, FREE = Weed free control and Weedy = Un- weeded control

Table 4: Effects of time of pre-emergence application of imazaquin on the control of wild poinsettia on and cowpea leaf dry weight

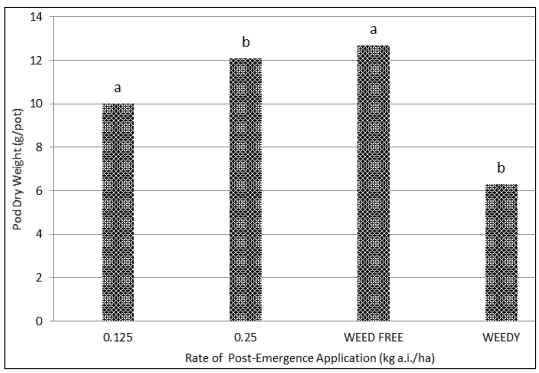
Treatment	WCE (%)	Weed dry wt. (g/pot)	Weed population	Cowpea Leaf dry wt. (g/pot)
Early-post emergence	73.3 b	14.5 c	56.8 b	9.2 a
Late-post emergence	24.9 c	39.3 b	88.5 a	4.5 b
Free	100.0 a	0.0 d	0.0 c	10.1 a
Weedy	0.0 d	54.0 a	99.0 a	3.1 b
SE ±	7.630	4.510	5.774	1.692

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
FREE = Weed free control and Weedy = Un- weeded control, WCE = Weed Control Efficacy



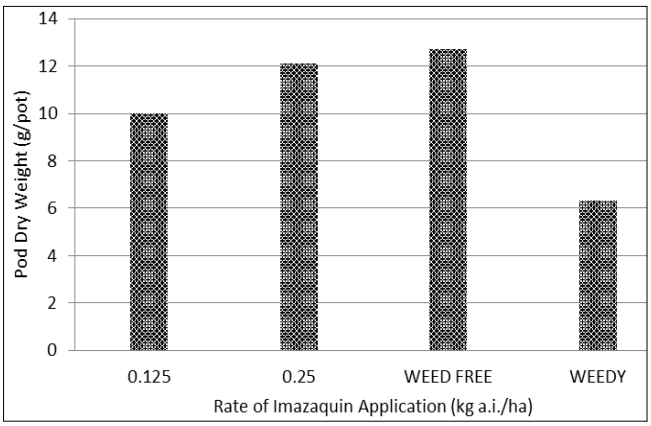
Bars bearing the same letter are not significantly different at 5% level of probability

Fig 1: Effect of time of post-emergence application of imazaquin on the dry pod yield of cowpea



Bars bearing the same letter are not significantly different at 5% level of probability

Fig 2: Effect of imazaquin concentration on cowpea pod dry weight



No significant difference between the rates of imazaquin application

Fig 3: Effect of imazaquin concentration on cowpea pod dry weight

Comparison of low and high concentrations of imazaquin

Use of imazaquin at 0.125 and 0.25 kg a.i./ha resulted in similar cowpea height of 246.8 and 240.8 cm, respectively (Table 5), as well as similar pod dry weight of 10.0 and 12.1 g/pot, respectively (Graph 3). The low and high concentrations of imazaquin treated pots produced cowpea plants with similar number of leaves and number of branches per plant, in addition to similar number of days to 50% flowering (Table 5).

Weed control efficacy, weed population and weed dry weight per pot were similar irrespective of the two different rates of application (Table 6.

Table 5: Effect of imazaquin concentration on the growth attributes of cowpea

Treatment	Plant height (cm)	No. of leaves/ plant	No. of branches/ plant	Days to 50% flowering
L	246.8	13.8 bc	1.8 b	50.0 b
H	240.8	15.3 ab	2.6 b	52.2 b
Free	216.0	23.5 a	4.3 a	50.3 b
Weedy	246.8	6.3 c	0.0 c	57.0 a
SE ±	Ns	1.552	0.408	2.152

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
FREE = Weed free control and Weedy = Un- weeded control

Table 6: Effects of imazaquin concentration on the control of wild poinsettia and cowpea leaf dry weight

	WCE (%)	Weed dry wt. (g/pot)	Weed population	Cowpea leaf dry wt. (g/pot)
L	39.15 b	31.7 b	74.50 ab	5.78 ab
H	59.03 b	22.1 b	70.83 b	7.90 a
Free	100.00 a	0.0 c	0.00 c	10.10 a
Weedy	0.00 c	54.6 a	99.00 a	3.10 b
SE ±	7.630	4.510	5.774	1.692

Means with the same letter(s) within a column are not significantly different at 5 % level of probability using DMRT.
WCE = Weed Control Efficacy

Discussion

In attributes like days to 50% cowpea flowering, pod dry weight, number of leaves per plant, cowpea leaf dry weight, weed population and cowpea height, the higher rate of imazaquin did not have a significantly better outcome than the lower rate. In the combine analysis, wild poinsettia was better controlled at the early post-emergence (10 DAS) application (73.3 % WCE) than late post-emergence (30 DAS) application (24.9 % WCE); it also had better weed population suppression., Similarly, based on decreases in lateral branch number and weed height at twenty eight days after treatment, wild poinsettia was more effectively controlled by the application herbicides at 5-7 cm than at 15-20 cm height in field and greenhouse studies. In the studies referred to, wild poinsettia was better controlled at earlier growth stage than at latter growth stage, this is similar to the outcome of this study where early post-emergence application resulted in better wild poinsettia control. Willard and Griffin (1993) [8] reported that late application of imazaquin, fomesafen, acifluorfen, and chlorimuron to *E. heterophylla* resulted in greater number of leaves and branches of the weed; this implies that the weed thrived in the plots that received late application of the herbicides.

Conclusion

It is recommended that early post - emergence application of imazaquin, as early as 10 days after sowing be preferred to applications as late as thirty days after sowing. In early application of imazaquin a rate as low as 0.125 kg a. i. /ha is as effective as a rate twice that (0.250 kg a.i./ha), this is an issue of lower cost and more environmentally friendly approach in addition to having similar cowpea yields such as pod and leaf dry weights per pot as well as similar number of branches per cowpea plant. In terms of wild poinsettia control the high and low rates had similar population, weed dry weight and weed control efficacy. It was observed that when the herbicide application is delayed for up to 30 days after sowing, due to logistics, the higher concentration becomes more effective since it provided greater number of cowpea branches per plant, lower weed biomass and better weed control efficacy. The lower rates of imazaquin of 0.125 kg a.i./ha is therefore recommended to be sprayed as early as ten days after sowing.

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