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Full Length Research Paper

Effects of Pendimenthalin and its Atrazine mixture on the weeds and Jute (*Corchorus olitorius*) seed

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The effectiveness of pendimenthalin (Stomp^R) and pendimethalin mixture with atrazine for early weed control in *Corchorus olitorius* L. was evaluated in Akure in the tropical rainforest zone of southwestern Nigeria. Stomp^R was applied at 1, 2, 3 and 4 L.ha^{-1} while the herbicide mixture was applied sequentially at 4 + 4 L.ha^{-1}. Plots were kept weedy and weeded twice to serve as controls. All herbicide treatments were significantly phytotoxic in plots treated with 1 to 2 L.ha^{-1} stomp^R. Herbicide phytotoxicity to the crop was more distinct in laboratory bioassay test suggesting the inhibitory action of herbicide on seedling radicle growth. Weed occurrence decreased significantly with herbicide application compared to untreated plots at 2 weeks after treatment (WAT) and more distinctly at the highest rates of herbicide application at 4 WAT. Thereafter however, weed occurrence and growth increased rapidly but weed cover reduced from 83.5% in Stomp^R treated plot to 34.9%, in plots treated with herbicide mixture. Also, surviving weed stands had comparable growth in plots treated with 1-2 L.ha^{-1} Stomp^R. *Euphorbia heterophylla, Calopogonium mucunoides, Chromolaena odorata, Ageratum conyzoides, Synedrella nodiflora Rottboella cochinchinensis* and *Commelina* spp. were predominant at the lower herbicide rates, but only E. *heterophylla* and C. *mucunoides* persisted as major weeds at the higher rates. Stomp at 1-2 L.ha-^{1} gave relatively effective weed control, but lower rates need to be used to minimize residue poisoning in harvested green leaves.

Keywords: Pendimenthalin, atrazine, weedy control and weed free control, weed occurrence.

INTRODUCTION

Leafy vegetables play crucial roles in alleviating hunger and food security. Thus, their importance cannot be overemphasized in diet and health of many people. Besides economic potentials, vegetables also have aesthetic value, useful in food preservation, prevent micronutrients deficiencies, enhance nutritional quality of diets and provide little dietary energy (Muller and Krawinkel, 2005). Epidemiological studies have shown that low intake of carotenoids, ascorbic acid and flavonoids found in vegetables and fruits increases the risk of cardiovascular diseases and other health challenges (Gandini et al., 2000; Joshipura et al., 2001; Liu et al., 2000; Liu et al., 2010; Kris-Etherton *et al*., 2002; Arts and Hollman, 2005). Vegetables contain antioxidants and micro nutrients that possess ability to neutralize free radicals or their actions (Cadenzas and Packer, 1996; Nicoli et al., 1999; Oke and Hamburger, 2002; Nakayoma and Yamada, 1995), thereby preventing terrible diseases of man such as cancer, cardiovascular disease, neural disorders, diabetes and arthritis (Sies, 1996; Yoshikawa et al., 2000; Devassagayam et al., 2004).

Weeds are major constraints in the production of vegetables. The infestation of weeds is early and critical in vegetable plots due to early weed competition. This can cause severe reduction in the yields and quality of vegetable crops through competition for nutrients and allelopathy from weeds (Ming, 1999; Jha and Dhakal, 1990; Rice et al., 1986). The negative effects of weeds are distinctly evident when jute is broadcast sown. The tropical climate encourages weed growth resulting in severe crop-weed competition (Saraswat 1999) and yield losses up to 75 to 80% in jute (Sahoo and Saraswat 1988). Weeds commonly associated with jute production in nearly all jute growing ecologies, includes monocot

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species such as, *Cynodon dactylon, Cyperus srotundus, C. iria, Eleusine indica, Echinochloa colona and Pennisetum purpureum* and dicot species such as, *Phyllanthus amarus, P. niruri, Euphorbia heterophylla, Tridax procumbens and Ageratun spp* (Saraswat, 1980).

Jute needs to be kept weed free through effective weed control. Cultural weed control methods commonly used by farmers consist of hand weeding, closer row spacing, mulching and use of competitive cultivars are inefficient. Also, they do not guarantee sustainable optimum yield and quality of vegetable products. Better vegetable production follows the control of weeds through the infusion of modern technology in herbicide application.

Chemical weed management ensures effective long-term weed kill and optimum vegetable production (Akobundu, 1987). Herbicides such as Alachlor, Metolachlor, Metobromuron, Linuron, Imazethapyr, Metribuzin, Trifluralin, Pendimethalin, Chlorthal Dimethyl and Chloroxuron singly or tank-mixed gave positive results in lettuce, onion, cucumbers, chilli peppers and tomatoes in Nigeria and other regions of the world (Lagoke *et al.,* 1988; Dusky and Stall, 1996). The weed control effectiveness of herbicides is complemented by quick canopy development of the vegetables. However, factors such as high soil moisture and temperature condition that are associated with vegetable growing areas make it difficult to ensure long-term weed kill in vegetable farms (Yayock *et al*, 1988).

The application of a tank-mixture of diuron + alachlor or norflurazon applied pre-emergence is effective for weed control in jute (Yayock *et al*, 1988). MSMA (4 $kg.ha^{-1}$) is effective in controlling *Cyperus rotundus* in row-planted jute. A post-emergence application of fluazifop-butyl (0.125-0.19 $kg.ha^{-1}$) suppresses *C. rotundus* and broadleaf weeds. Fluchloralin, oxyfluorfen, thiobencarb and dalapon have also been effectively for pre-emergence weed control in jute (Biswas, 1986).The application of fenoxaprop-p-ethyl at 56.25 and quizalofop 62.5 g/ha in jute may appreciably manage the grassy weeds and also gave higher seed yield comparable to that of hand weeding twice (Sinha et. al., 2009).

Pendimethalin (IN-(1-ethylpropyl)-3, 4-dimethyl-2, 6-dinitrobenzenamine) ($Stomp^R$) belongs to the dinitroaniline group of herbicides. It is the only member of this group that can be applied as pre-emergence, pre-plant incorporated and post-emergence herbicide (Akobudu, 1987). Pendimethalin is primarily active on grass weeds and also effectively controls broad leaves (Das, 2011). It has been reported to be selective to over sixty crops and vegetables (Das, 2011), including cotton (Shaner *et.al*., 1998), maize, sorghum, cowpea and soybean (Akobundu, 1987). The effectiveness of pendimenthalin as pre-emergence weeds control herbicide in kenaf in Nigeria is established. Pendimethalin mode of action in susceptible species is inhibition of mitotic cell division in developing root systems (Vencill 2002). The Phytotoxic effects of pendimethalin on weeds are evident in inhibition of lateral root development, stunting of shoot, development of dark green color, swelling and brittleness of stem or the hypocotyl of seedlings (Akobundu, 1987; Das, 2011).

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) (Gesaprim) belongs to the symmetrical triazine group of herbicides. It has a broad spectrum of action by effectively controlling broadleaves and grasses in croplands (Akobundu, 1987). Atrazine is a foliar as well as root absorbed herbicide. The mode of action of atrazine is the inhibition of photosynthesis and its site of action is the chloroplast.

The study was conducted to ascertain weed control effectiveness of pendimethalin and pendimethalin + atrazine in jute, in order to have broader spectrum of herbicides for weed management in jute.

MATERIALS AND METHODS

The experimental site was a one-year fallow in a tropical rainforest environment at the Teaching and Research Farm of the Federal University of Technology, Akure (237m; $7^0$16'N, 5^0 12'E) in 1997. The fallow vegetation was slashed to ground level to create a bare soil surface for herbicide application. Gross experimental area was 17.2 x $6.5m^2$ with a net area of $14.2x4.5m^2$ and plot size of $2.1x1.5m^2$. *C.olitorius* seeds were treated with hot water to break seed-coat dormancy before sowing. The seeds were planted in rows. Pendimethalin and it mixture with atrazine were applied after planting at different rates. The plants were thinned to two plants/stand using an inter row spacing of 50 cm and intra row of 5 cm. The treatments were arranged in Randomized complete Block Design (RCBD) with three replicates. The weed free plots were weeded twice at 3 and 5 WAP.

Treatments list

1. Weedy control (WyC)
2. Weedfree (Wf)
3. 1 L.ha-1 pendimethalin (P1)
4. 2 L.ha-1 pendimethalin (P2)
5. 3 L.ha-1 pendimethalin (P3)
6. 4 L.ha-1 pendimethalin (P4)
7. 4 + 4 L.ha-1 pendimethalin + atrazine (P+A)

Data Collection

Data were recorded on weed flora composition at 2 WAT. Weed survival and crop injury at 2 WAT, weediness at 2, 4 and 7 WAT were visually rated on a scale of 0 to 10. Fresh yield of jute was determined using a weighing balance at 7 WAT. At 4 and 7 WAT, two quadrat frames

Table 1. Weed flora composition of experimental plots at 2 weeks after treatment.

Family	Weed species	Life cycle	Morpho – logy	Weedy Wy	Weed-free Wf	Treatments 1 (P_1)	2 (P_2)	3 (P_3)	4 (P_4)	4 + 4 (P+A)
						------------- L.ha^{-1}				--------------
Asteraceae	*Ageratum conyzoides*	A	B	a	a	a	-	-	b	-
	Aspilia africana	A/P	B	-	-	-	b	-	-	-
	Chromolaena odorata	P	B	-	-	a	-	b	b	-
	Synedrella modiflora	A	B	-	-	a	b	a	b	-
Poaceae	*Rottboellia cochinchinensis*	A	G	a	a	a	-	-	-	b
	Pennisetum purpereum	P	G	b	-	-	-	-	-	-
Euphorbiaceae	*Euphorbia heterophylla*	A	B	a	a	a	a	a	a	a
Portulacaceae	*Talinum triagulare*	P	B	a	a	-	-	b	-	b
Leguminoseae	*Calopogonium mucunoides*	A	B	a	a	b	a	a	a	a
Cyperaceae	*Cyperus rotundus*	P	S	-	-	-	b	-	-	-
Commelinaceae	*Commelina diffusa*	P	Sp	-	-	-	b	-	-	-

[1]A = annual, P = perennial, B = broadleaf, G =grass, S = sedge, Sp = spiderwort, a = major weed, b = minor weed.
P_1 = 1.L.ha^{-1} Pendimethalin, P_2 = 2.L.ha^{-1} Pendimethalin, P_3 = 3.L.ha^{-1} Pendimethalin, P_4 = 4.L.ha^{-1} Pendimethalin
P + A = 4 + 4 L.ha^{-1} Pendimethalin + Atrazine.

were placed diagonally in each plot and weed species were identified hand pulled and counted to obtain weed densities. Thereafter weed samples were oven dried at 80^{0}C for 48 hours to determine dry weight of weed biomass.

Bioassay test using soil samples from treated plots and herbicide at the specified concentrations were conducted to evaluate crop seed germination, seedling emergence, shoot and root growth, and seedling injury at 7 days after treatment (DAT). The seed germination percentage was determined. The herbicide injury on seedling was visually rated. The growth of the shoot and root were measured using a ruler. Data collected were analyzed statistically using Analysis of Variance (ANOVA) procedures. Treatment means were separated using the Least Significant Difference test (LSD at P<0.05).

RESULTS

Weed flora composition of the experimental plots as recorded at 2 WAT covered 7 plant families and composed mostly members of the family Asteraceae (Table 1). Weed species were predominantly annual broad leaves (63.6%), followed by a few annual grass species (27.3%), sedge and spiderwort (1%) each. In the weedy plots, most weed species were major weeds (83.3%), and one minor weed (16.7%). Weed free plots had only major weeds. A Similar observation was recorded in plots treated with the lowest rate of herbicide (I L.ha-I). Apparently, the latter two treatments were comparable in weed flora. On the other hand, plots treated with 2 L.ha^{-l} pendimethalin had considerably more minor weeds than major weeds whereas plots treated with 3 L.ha^{-l} herbicide had slightly more major weeds than minor weeds. At 4 L.ha^{-}I pendimethalin major weeds were less than minor weeds were less than minor weeds, whereas plots treated with herbicide mixture had equal proportion of both and minor weeds. Generally, weedy plots had more weed spp than herbicide treated plots was observed from plots treated with the herbicide application. On average across treatments, observed weeds were mostly minor species (63.6%) while major species comprised only (36.4%).

On the other hand, herbicide treated plots had equal proportions of both

Table 2. Weed situation of field plots sprayed pre-emergence with pendimethalin and pendimethalin + atrazine[1].

Treatment	Weediness 2 WAT	Weediness 4 WAT	Weediness 7 WAT	Weed survival 2 WAT	Crop seedling injury 2 WAT
	--	%	---		-------
Weedy Control (Wy)	81.7^{a}	91.7^{a}	100.0^{a}	61.7^{a}	-
Weed-free control (Wf)	81.7^{a}	-	1.7^{c}	78.3^{b}	-
1 L.ha^{-1} pendimethalin (P_1)	63.3^{b}	73.3^{b}	100.0^{a}	31.7^{c}	41.7^{d}
2 L.ha^{-1} pendimethalin (P_2)	51.7^{c}	63.3^{c}	100.0^{a}	33.3^{c}	41.7^{d}
3 L.ha^{-1} pendimethalin (P_3)	51.7^{c}	48.3^{d}	95.0^{a}	21.7^{d}	60.0^{c}
4 L.ha^{-1} pendimethalin (P_4)	41.7^{d}	33.3^{d}	95.0^{a}	13.3^{e}	76.7^{b}
4 L.ha^{-1} pendimethalin + 4 ha^{-1} atrazine (P + A)	13.3^{e}	16.7^{e}	26.7^{b}	6.7^{f}	91.7^{a}
LSD (0.05)	3.68	4.50	6.75	4.15	4.15

[1]WAT = Weeks after treatment, Means followed by the same letter are not significantly different.

major and minor species. The major species include *A. conyzoides*, *S. nodiflora, R. cochinchinesis, E. heterophylla* and *C. mucunoides.*

At 2 WAT, weed (Wy) and weedfree (Wf) plots had significantly higher weed cover and this decreased significantly with increasing rate of herbicide applications although plots treated with 2-3 L.ha^{-l} had comparable weed cover (Table 2). A similar observation was recorded at 4 WAT. Similarly, weed cover in plots treated with 3 and 4 L.ha^{-l} were comparable. At 7 WAT, plots kept weedy and those treated with increasing rate of pendimethalin (l-4 L.ha^{-l}) had comparable weed cover. However, significantly less weed cover were recorded in plots treated with the herbicide mixture and weed free (Wf) plots. Across sampling times (2, 4 and 7 WAT), a steady increase in weediness was obtained in plots kept weedy and those treated with 1 to 2 L.ha^{-1} pendimethalin and herbicide mixture. On the other hand, weedliness decreased initially (4 WAT) but increased rapidly as in plots treated with 3 and 4 L.ha^{-1} pendimethalin thereafter.

Observations recorded at 2 WAT indicate that increasing rate of herbicide application significantly reduced weed survival. On the other hand, crop seedling phytotoxicity increased significantly with higher rate of herbicide application.

WEED DENSITY AND BIOMASS

The highest weed density was recorded at 4 WAT of plots treated with 4 L.ha^{-l} pendimethalin, but there was no significant difference between the latter and weedy plots and plots treated with 1, 2, and 3 L.ha^{-1}Table 3. The least weed density was obtained in plots treated with herbicide mixture. There was significant difference in weed biomass obtained from plots kept weedy and those treated with all rates of pendimethalin. As recorded earlier (4 WAT), the least weed biomass was obtained in plots treated with herbicide mixture. Differences in these two weed growth parameters among treatments were apparently the same although the highest values were recorded in plots treated with 1 L.ha^{-1} pendimethalin unlike at 4 WAT.

CROP SEEDLING GROWTH AND YIELD

Unlike in herbicide treated plots where crop seedling failed to establish, weedy and weed free plots has complete seedling emergence and establishment. Shoot fresh yield of plant sample collected from weed free plots was significantly higher than that from weedy plots. Differences in root and total fresh yield also followed the same pattern. In addition, plant samples harvested from weed free plots were observed to produce more stem than leaf fresh yield.

BIOASSAY TESTS

Observations during laboratory test indicated a significant decrease in crop seed germination. Seedling growth decreased with increasing concentration of herbicide solution. However, unlike seed germination, seedling shoot and root growth showed considerable decrease in length with increasing concentration of herbicide solution compared to the untreated control. Also, this is true for seedling growth in herbicide concentration higher than 2 L.ha^{-1}.On the other hand, crop seedlings showed significant herbicide injury with increasing concentration

Table 3. Weed density and biomass production during *C. olitorius* growth[1].

Treatment	4 WAT Weed density	Weed biomass	7 WAT Weed density	Weed biomass
	No.m^{-2}	g.m^{-2}	no.m^{-2}	g.m^{-2}
Weedy Control (Wy)	161.7^{ab}	24.4^{a}	135.0^{bc}	111.7^{a}
Weed-free control (Wf)	0.0^{c}	0.0^{c}	0.0^{d}	0.0^{c}
1 L.ha^{-1} pendimethalin (P_1)	189.3^{ab}	27.1^{a}	185.3^{a}	122.3^{a}
2 L.ha^{-1} pendimethalin (P_2)	198.0^{ab}	26.6^{a}	169.7^{ab}	101.0^{ab}
3 L.ha^{-1} pendimethalin (P_3)	239.3^{a}	22.4^{a}	148.0^{abc}	98.3^{ab}
4 L.ha^{-1} pendimethalin (P_4)	239.3^{a}	22.4^{a}	108.0^{c}	73.1^{b}
4 L.ha^{-1} pendimethalin + 4 ha^{-1} atrazine (P + A)	89.7^{bc}	8.1b^{c}	117.0^{c}	70.0^{b}
LSD (0.05)	113.46	12.79	44.71	40.00

[1]WAT = Weeks after treatment, Means followed by the same letter are not significantly different.

Table 4. Bioassay tests on crop seed germination and growth in herbicide solution and treated soils 7 days after treatment[1].

Treatment	Crop seed germination	Shoot length	Root length	Seedling injury	Seedling emergence	Shoot length	Seedling injury
	%	cm	cm	%	%	cm	%
Untreated control	100.0^{a}	22.9^{a}	14.3^{a}	0.0^{f}	95.0^{a}	23.7^{a}	16.9^{a}
1 L.ha^{-1} pendimethalin	88.7^{b}	7.0^{b}	3.1^{d}	18.3^{e}	85.0^{b}	18.8^{a}	14.2^{b}
2 L.ha^{-1} pendimethalin (P_2)	84.7^{b}	6.0^{c}	2.6^{c}	31.7^{d}	83.3^{b}	20.8^{a}	13.7^{b}
3 L.ha^{-1} pendimethalin (P_3)	72.7^{c}	55.7^{c}	2.5^{c}	46.7^{c}	86.7^{ab}	25.3^{a}	16.4^{a}
4 L.ha^{-1} pendimethalin (P_4)	68.3^{c}	5.3^{c}	2.4^{c}	66.7^{b}	83.3^{b}	19.4^{a}	14.7^{ab}
4 L.ha^{-1} pendimethalin + 4 L.ha^{-1} atrazine (P + A)	46.7^{d}	5.3^{c}	2.3^{c}	76.7^{a}	85.0^{b}	23.9^{a}	14.2^{b}
LSD (0.05)	6.28	0.78	0.53	3.45	9.41	14.85	2.19

[1]Mean followed by the same letter(s) are not significantly different.

of herbicide solution. Seedling injury in herbicide mixture was more than 4 times more severe than 1 L.ha^{-1} pendimethalin solution (Table 4).

After 7 days, crop seedling emergence from both treated and untreated plots were comparable. Also, seedling emergences from treated soils were apparently variable but comparable. On the other hand, seedlings showed no significant differences in shoot growth response in both untreated and treated plots. Although fairly uniform, differences in seedling root growth were significant; the longer shoots were obtained in seedlings in untreated soil and soil treated with the highest rate of pendimethalin and the least in soil treated with the lowest rate of pendimethalin.

DISCUSSION

A typical rainforest agro-ecosystem is characterized by a high diversity of weed species (Smith, 1996).This is particularly distinct under conventional tillage cropping systems where weed seeds buried deep in the soil horizons are inadvertently brought to the top soil (Zimbahl et al.,1986).Similarly, in fallow no-tillage systems complex weed flora is usually observed with a high possibility of diverse seed sources, output and characteristics. These accounted for the wide diversity in weed flora composition in this trial.

In weedy plots, weed species had optimal environment for growth and reproduction while also escaping from herbicide treatment as in treated plots. This favoured the predominance of major weeds compared to herbicide treated plots in which major weeds succumbed partially or complete to herbicide injury and had their growth and persistence drastically affected. The same reason accounts for plots treated with the lowest rate of herbicide which compared in weed flora composition with weedy plots.

However, the variability recorded in weed flora in plots treated with higher herbicide rates could be due to weed growth habits, type and response to herbicide soil interactions (Akobundu, 1987). In plots treated with the herbicide mixture, the admixture of weed types reflects the differential phytotoxicity of component herbicides to different weed species in the treated vegetation. Pendimethalin is primarily a grass herbicide but it also effectively controls some broadleaf weeds (Mclntyre and Barbe, 1995; Das, 2011). Similarly, atrazine is primarily a broadleaf herbicide but can effectively suppress the growth of some seedling grasses and sedges (Das, 2011). Generally, the predominance of annual broadleaves indicates a shift in weed flora under herbicidal weed control practices.

Except for the plots treated with the lowest rate, pendimethalin apparently completely eliminated *R. cochinchinesis* stands at P_2 to P_4 but failed to suppress the growth of *A. conyzoides, S nodiflora, E. heterophylla* and *C. mucunoides* especially at the lowest rates confirming previous reports (Akobundu, 1987; Das, 2011). Similarly, the herbicide mixture also suppressed the growth and spread of most weeds except *E. heterophylla* and *C. mucunoides.*

Evidently, weed species growth, cover and survival were adversely reduced by increasing rate of herbicide application. This trend was particularly distinct in P + A in which the weed flora were severely injured by herbicide components resulting in complete elimination of the most problematic vigorous species and suppressed growth of the less vigorous ones. On the other hand, increasing rate of herbicide caused significant increase in crop seedling growth. This probably accounts for the reduced stand establishment observed in different herbicide treated plots although more obvious at rates high than 3 $L.ha^{-1}$. It is evident that *C. olitorius* seedlings tolerate lower rates of pendimethalin (1 – 2 $L.ha^{-1}$) initially after establishment but succumb over time resulting in death of stands. It is therefore suggested that much lower rates be tested for possible complete tolerance without adverse effect on stand survival.

Although not significantly different, greater weed occurrence, growth and cover were obtained in herbicide treated plots within one month than in the weedy plots, in addition to the increase in weed density with increasing herbicide rate. The possibility of growth enhancement in weed flora with herbicide treatment is strongly indicated during this initial period after herbicide application. The contribution of loss of pendimethalin action due to degradation is also evident (Akobundu, 1987; Weber 1990).

However, the significant decrease in weed flora with increasing herbicide application indicates the adverse effect of herbicide on photosynthesis, weed growth and biomass accumulation particularly in plots treated with the herbicide mixture. At 7 WAT, a large proportion of the herbicide has apparently been lost from topsoil, and this resulted in a steady decline in weed density, and a more distinct reduction in weed biomass production with increasing herbicide application. These account for the rapid increase in weed density, and a more distinct reduction in weed biomass production with increasing herbicide rate in plots treated with lowest pendimethalin rate and herbicide mixture at 4 and 7 WAT as contrasted with the decrease in weed densities in the former plots. A similar reason accounts for the rapid increase in weed biomass production between the two sampling times in all trial plots except weed free plots. Loss of herbicidal efficacy through environmental degradation is a major limitation to the effectiveness of pre-emergence herbicide in tropical soils (Akobundu, 1987).

Observation from bioassay tests apparently show that *C. olitorius* seeds can germinate appreciably in pendimethalin treated field plots in spite of the significant reduction in percent germination in solution and treated soils. The difference in percent germination in solution of treated soil containing herbicide mixture is mainly due to leaching of herbicide molecules from treated soil and microbial degradation. This also accounts for the appreciably high seedling emergence across herbicide rates.

On the other hand, differences in shoot and root lengths of *C. olitorius* seedling particularly in herbicide solution reflect the primary mechanism of action of pendimethalin: inhibition of lateral root development, stunting of seedling shoot, swelling and brittleness of stem. However, while herbicide solutions cause severe malformation of seedlings, treated soils exhibited less adverse effects on shoot and root growth in emerged seedlings. The possible contribution of leaching and microbial degradation to loss of herbicidal activity is also indicated. This is in agreement with Akobundu, (1987) and Weber, (1990).

Data recorded on crop seedling injury in bioassay test strongly confirm the phytotoxic effect of pendimethalin and pendimethalin + atrazine mixture on *C. olitorius* growth and development during their application for early weed management. This, in addition to the poor phytotoxic effect of these herbicides on seedling emerge weed management in *C. olitorius.* However, for efficient weed management and optimum production of edible leaves, it is apparently important to combine lower herbicide rates with supplementary hand weeding 3 to 4 WAT in an integrated weed management system.

CONCLUSION

Pendimethalin application effectively controlled most of the observed weeds in the experimental plots particularly *R. cochinchinensis* with increasing rate of herbicide application. However, herbicide treatments were phytotoxic to crop seedlings and completely prevented their establishment. It is therefore suggested that lower rates of pendimethalin and its mixture with atrazine be evaluated for weed control in this vegetables since this is likely to ensure optimum yield and prevent possible accumulation of toxic herbicide residue in the edible leaves. Alternatively, there is need to determine the re-cropping interval of maize plot treated with pendimethalin for subsequent cropping with *C. olitorius* and the possibility of intercropping. In either case, the need for one supplementary hand weeding preferably 3 – 4 WAT is important in this study.

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