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Allelopathic Effect of some Weeds on the Germination of Seeds of Selected Crops Grown in Akwa Ibom State, Nigeria

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Abstract The allelopathic potentials of six dominant weeds at the Teaching and Research Farm of the Akwa Ibom State University and adjoining areas, often used for mulching and green manuring, were evaluated on the germination of the seeds of six commonly grown crops of the region. Extracts from 500g of finely chopped shoots and roots each of *Aspilia africana* (Pers) C. D. Adams, *Emilia sonchifolia* (L) DC, *Crotalaria retusa* L, *Chromolaena odorata* (L) King & Robinson, *Panicum maximum* L., and *Cyperus esculentus* L., were obtained with one litre of distilled water. These were applied to seeds of *Zea mays* L., *Citrullus lanatus* Thunb, *Abelmoschus esculentus* (L) Moench, *Vigna unguiculata* (L) Walp, *Glycine max* (L) Merr, and *Arachis hypogaea* L. in petri dishes. The equivalence of 0, 2.0, 4.0, 8.0 and 12.0 Mg ha^{-1} of finely chopped fresh shoots of each weed were also applied to 1.0kg of heat-sterilized soil in planting polybags as mulches. Water extracts of the weeds (shoots and roots) reduced germination counts of the seeds by 10 to 100%. *Cyperus esculentus* L.shoots extracts was the most phytotoxic, followed by *Panicum maximum* L and *Chromolaena odorata*. The decomposing mulches showed varied but less inhibitory effects on the seeds with a trend toward increasing inhibitory power with increasing mulch level and decreasing seed size. The results revealed that a possible relationship between the low seed germination and poor seedling growths often observed in the area. However, further studies are needed to confirm the findings.

Keywords: *allelopathy, local weeds, decomposing mulches, seed germination, southeastern Nigeria*

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1. Introduction

The benefits of organic mulches in tropical agro ecosystems have been well documented [1,2,3]. Awodun and Ojeniyi [4] observed that apart from the influence of organic mulches on soil physical properties, they also enhance biological activity and add nutrients to the soil thereby enhancing its productivity. Bruce *et al*. [5] recommended that mulches should be applied in the decomposing state, instead of as completely decomposed material because of the added benefit of providing ingredients for persistent biological activity essential for creating a physically stable soil surface. However, it is known that plant residues of crops, weeds or natural vegetations left on, and in the soil, release assorted chemical compounds into the soil during decomposition. These include phyto-growth inhibitors, allelochemics or allelochemicals [6,7] The chemical compounds interfere with the growth of other plants and often adversely affect the yields of crop plants through the process of allelopathy [8].

Although allelopathy may be defined as any direct or indirect stimulatory or inhibitory effect of one plant (or microorganism) on another through the medium of chemical compounds released into the environment. Release of such chemical compounds, or allelochemicals, is held as a major factor in regulating the structure of plant communities in both natural and agroecosystem [9, 10]. The regulation is accomplished, in part, by generating biotic stresses for germinating seeds in the form of allelopathic interferences. As the seed is an important plant organ and most sensitive to allelochemicals, their germination has generally been the preferred bioassay in allelopathic studies [11]. Use of seed germination results is of advantage since the process constitutes a critical step in the propagation and cultivation of most crop species [12].

Farmers in southeastern Nigeria who cultivate areas under short duration (2 – 3 years) fallows which are covered by such invasive weeds as *Chromolaena odorata* and *Panicum maximum* often complain about poor seedling emergence. This is especially so if the seeds were planted where cleared vegetation were still fresh and decomposing on the soil surface, but rarely where they were burnt or left for long periods to dry out. The situation thus suggest allelopathic interference.

The dominant weeds at the Teaching and Research Farms of the Akwa Ibom State University, Obio Akpa and adjoining areas including *Aspilia africana* (pers.) CD Adams (wild marigold), *Emilia sonchifolia* (L) DC., (shaving brush), *Crotalaria retusa* L. (rattle box), *Chromolaena odorata* (L) King and Robinson (siam weed), *Panicum maximum* L. (guinea grass) and *Cyperus esculentus* L. (tiger nut). Decomposing residues of these weeds are commonly left on the soil surface as mulches. Some of the most commonly grown edible seeds in this area are *Zea mays* L (maize), *Citrullus lanatus* Thumb (melon), *Abelmoschus esculentus* (L) Moench (okra), *Vigna unguiculata* (L) Walp (cowpea), *Glycine max* (L) Merr.(soya bean), and *Arachis hypogea* L. (groundnut). This study was carried out to evaluate the allelopathic potentials of these weeds on the germination of the listed seeds.

2. Materials and Methods

2.1. Weed Collection and Preparation of Samples

Weeds for the study were collected in April, 2012 from the Teaching and Research Farms of the Akwa Ibom State University, Obio Akpa campus situated between latitude 4^{o}30' and 5^{o}30'N and longitude 7^{o}30' and 8^{o}20'E. Whole plants were carefully dug up using a digging fork to loosen the soil around them. Plant shoots were detached from the root with a knife and both sections were spread out on a polythene cover under a shed for 48 hours to wither slightly.

2.2. Laboratory Study

The tops and roots of each weed species were chopped separately with a knife into very tiny bits and 500g of the materials added to 1.0 litre of distilled water in plastic buckets, vigorously stirred and allowed to stand for 24 hours. These were then vigorously re-stirred and filtered into wash bottles for use. Two hundred and fifty two (252) petri dishes double layered with Whatman No. 1 filter paper were taken and divided into two (2) sets of 126 petri dishes – one set for water extracts of tops and the other set for extracts of roots. Each set was further divided into six (6) subsets of 21 petri dishes each, with a subset allocated to a crop.

Ten (10) seeds were sown in each petri dish and moistened with 25mls of an appropriate water extract of the weed. There were three (3) replications of each treatment (an aqueous extract plus a type of seed). Twenty-five (25mls) of distilled water was applied to the control. Filter paper linings of each petri dish were moistened daily with an appropriate extract to prevent them drying up before final germination counts (7 days after sowing). The petri dishes were kept in a growth chamber at room temperature until the final germination count. Germination data obtained were subjected to analysis of variance (ANOVA). Means were separated using the Duncan's Multiple Range Test (DMRT).

2.3. Poly-bag Study

One (1) kilogram of heat sterilized loamy soil was packed into each of 540 large perforated poly-bags with enough space at the top to hold mulching material. Freshly cut and finely chopped tops of each of the weeds were applied as mulch to the soil in each poly-bag at five (5) levels equivalent to 0, 2.0, 4.0, 8.0 and 12.0 Mgha^{-1}. These were designated treatments A, B, C, D and E, giving five (5) treatments per weed. Distilled water was applied to each poly-bag to wash the mulch into the soil twice (2 times) daily for two (2) days after which twenty (20) certified seeds of each test crop were sown through the mulch according to treatment. Every treatment was applied to each of the six (6) test crop seeds and replicated three (3) times. The poly-bags were subsequently watered every 24 hours until final seedling emergence counts were taken (10 days after sowing). Seedling emergence data were subjected to ANOVA and means were separated by DMRT.

3. Results and Discussion

Germination of seeds (%) as affected by aqueous extracts from both shoots and roots of test weeds are presented in the Tables 1. Tables 2 and 3 show data on the effects of the decomposing mulches of the weeds shoots on the germination of the seeds and emergence of the seedlings.

3.1. Water Extract of the Weeds

Comparing data in Table 1 with those in Table 2 and Table 3, it can be observed that water extracts of the weeds had a more potent inhibitory effect on germination of the seeds than the decomposing mulches. For example, water extract of *Aspilia africana* shoots allowed 90, 40, 30 and 20 per cent germination of maize, okra, cowpea and groundnut respectively (Table 1), but its decomposing mulches did not significantly ($p < .05$) inhibit the germination of these seeds irrespective of level of application (Table 2). Also, while the water extracts of *Cyperus esculentus* shoots allowed 0% germination of maize, melon and okra (Table 1), only high level of its decomposing mulch application completely prevented the germination of those seeds (Table 3). This may be due to the seeds being in more direct and intimate contact with higher concentrations of allelochemicals in the water extracts than in the soil, and suggests that the effects of the allelochemicals involved are concentration dependent. The result also suggests that the soil played some mediatory role in the allelopathic interactions observed. There are several publications reporting on interactions of allelochemicals with the soil [11,12,13]

Water extracts of shoots and roots of some of the weeds appear to show different degrees of inhibitory effects on the same seed (Table 1). For example, water extracts of the shoots of *Crotolaria retusa*, *Chromolaena odorata* and *Panicum maximum* allowed 70, 40 and 30 per cent germination of maize respectively ,whereas their root extracts allowed 90, 90 and 80 per cent germination respectively (Table 1). The same trend is also observed with extracts of the same weeds on the germination of melon, okra, cowpea and soya bean (Table 1). Water extracts of the shoots of some of the weeds appear to be more deleterious in their effects than water extracts of their roots. This was the case with *Crotolaria retusa*, *Chromolaena odorata* and *Panicum maximum* on the germination of maize and okra, and *Chromolaena odorata* and *Panicum maximum* on the germination of maize, melon, okra, cowpea, and soya bean seeds. For example, extracts of *Chromolaena odorata* shoots allowed 40, 10, 10, 40 and 10 per cent germination of maize, melon, okra, cowpea and soya bean seeds respectively (Table 1).

The equivalent germination percentages with respect to its root extract were 90, 30, 60, 50 and 20 for maize, melon, okra, cowpea and soya bean respectively (Table 1). However, the trend was reversed with some weeds and some crops. For example, water extracts of shoots of *Aspilia africana* allowed germination percentages of 90, 50, 40, and 30 for maize, melon, okra and cowpea respectively while water extracts of the roots allowed germination percentages of 80, 30, 20 and 10 respectively, thereby showing a greater inhibitory effect [14]. Thus, the inhibitory effect of the shoots or root of a particular weed appears to depend on the nature of the weed and that of the target seed. However, some researchers have pointed out that leaf litter may be more or less phytotoxic than root litter [15]

Water extracts of shoots and roots of *Cyperus esculentus* were the most severe in its inhibitory effect on the germination of the seeds. While extracts of its shoots allowed only 10 and 20% germination of cowpea and groundnut and 0% of other seeds respectively, its root extract allowed only 10% germination of maize, and 0% germination of all other seeds (Table 1).

3.2. Effect of Decomposing Mulches

The decomposing mulches showed less inhibitory effect on the germination of the seeds than the water extracts (Tables 2 and 3). This may be attributed to reduced concentrations of released allelochemicals reaching the seeds due to levels of applied mulch, seed planting depths, and possibly amounts of such soil components as organic matter and clays separating the mulches from the seeds. Data in Tables 2 and 3 show a general trend toward reduction in germination counts with increase in mulch levels, suggesting elevated amounts of phytotoxic agents being released into the soil as the mulch levels increased. Germination of small-sized seeds appears to be most adversely affected. This may be because more concentrated amounts of allelochemicals reached the smaller-sized seeds planted at much shallower depths than the larger seeds. Mohler [16] noted that allelochemicals released from decomposing mulches on the soil surface may not diffuse sufficiently rapidly and deeply into the soil profile, thus their effects on seed germination would be greatly reduced. This may partly explain why the germination of larger-size seeds was less affected by released allelochemicals.

3.2.1. *Aspilia Africana* (Pers) Adams. , *Emilia sonchifolia* (L.) DC. and *Crotolaria retusa* L.

With *Aspilia africana*, no level of the decomposing mulches used seemed to produce allelochemicals at the inhibition threshold level (i.e. lowest phyto-toxin concentration required to produce appreciable inhibitory effect) with respect to maize, cowpea and groundnut (all relatively large-sized) seeds (Table 2) . The germination of these seeds were not significantly (p<.05) inhibited compared to what obtained with water extracts of its shoots and roots (Tables 1 and 2). With respect to melon and soya bean (both small-sized) seeds the smallest level of *Aspilia* mulch (2.0 $Mgha^{-1}$) apparently produced phyto-toxins which reached the inhibitory threshold.

This mulch level gave 40 and 65% germination of melon and soya bean respectively which were significantly (p<.05) lower than the 90 and 100% germination of the same seeds respectively for the control. Apart from seed size relationship with planting depth earlier discussed, its surface-to-volume ratio may also affect its sensitivity to allelochemicals. It is well known that the surface-to-volume ratios of small-sized seeds are greater than those of relatively large-sized ones. This means, in most cases, that their exposure per unit mass to phyto-toxic agents in a planting medium, like the soil would be greater and their germination more adversely affected.

However, this may not always be the case. For example,the phyto-toxins produced by *Aspilia africana* mulches did not significantly (p<.05) inhibit the germination of okra, a relatively small-sized seed, irrespective of level of mulch application (Table 3). Thus factors other than seed size play some role in small-sized seeds sensitivity to allelochemicals. One such factor, for example, is the species genetic make-up which is known to influence its response to allelopathic stress signals [17,18,19]. Studies by Kiran *et al*. [20] also showed that *Aspilia africana* had mild to severe inhibitory effects on the germination of several seeds especially those of cereals, including wheat and rye.

The decomposing mulches of *Emilia sonchifolia* and *Crotalaria retusa* affected germination of the test seeds in a slightly different pattern (Table 2). After showing initial inhibitory effect on the germination of cowpea, soya bean and groundnut seeds by *Emilia sonchifolia* ,and on the germination of maize, cowpea and groundnut seed by *Crotalaria retusa*, subsequent germination percentages of those seeds as affected by both weeds remained statistically (p<.05) similar irrespective of mulch level. The phyto-toxins produced by both weeds apparently did not reach the IC_{50} (toxin concentration causing 50% inhibition) with respect to these seeds irrespective of mulch level. Many factors may be responsible for this. The allelochemicals involved may have been unstable in the soil solution which caused it to quickly disintegrate and its actions short lived. However it has been pointed out that the aglycones derived from the breakdown of the allelochemicals, benzoxazinones, during the decomposition of plant materials quickly disintegrate in aqueous solutions to produce bioactive substances which are less phyto-toxic. Also, while interacting with the chemical components of the seeds, a detoxification of allelochemicals released by the two weeds may have occurred. Einhellig [21] and Schulz and Friebe [22] put forward detoxification as an explanation for the resistance of certain plant species against some allelochemicals.

There was also a trend of increase in the inhibition of germination with increase in mulch levels on the relatively small-sized seeds – melon and okra (by *Emilia*), and melon, okra and soya bean (by *Crotalaria*) (Table 2). This may be attributed, not only to the greater exposure to allelochemicals as a result of seed size, but also to the nature of elicited allelochemicals and the sensitivity of the affected seeds to the particular allelochemicals. The nature of the allelochemicals produced by the decomposing *Emilia sonchifolia* shoots and seed sensitivity to them may also explain the observed increase in inhibitory effect on maize germination with increase in mulch level compared to the statistically ($p<.05$) similar per cent germination of soya bean (a relatively small-sized seed) irrespective of mulch level (Table 2). Schulz and Friebe further noted that the same allelochemicals may affect different targets in different ways. The inhibitory effect on the germination of seeds of many crop species by *Emilia sonchifolia* and *Crotalaria retusa* have also been reported by Naudin and Balarabe. [23].

3.2.2. *Chromolaena odorata* (L.) King and Robinson, *Panicum maximum* L. and *Cyperus esculentus* L

The decomposing mulches of *Chromolaena odorata* and *Panicum maximum* significantly ($p<.05$) lowered the germination percentages of all the test seeds. Data in Table 3 show that the inhibitory effects increased with increase in mulch levels. This should be expected as increase in mulch levels also increases the amount (concentration) of allelochemicals released onto the target. Alam *et al*. [24] noted in their study that the higher the mulch level, the higher the concentration of allelochemicals released. Okra and soya bean appear to be the most sensitive of the test seeds to allelochemicals elicited by the two weeds. With treatment B ($2.0Mgha^{-1}$) of *Chromolaena* shoots, 35 and 25 per cent germination of okra and soya bean respectively were obtained (Table 3). The same level of *Panicum maximum* mulch allowed 40 and 40 per cent germination of okra and soya bean respectively (Table 3). This means that $2.0Mgha^{-1}$ of the decomposing mulches of both weeds produced phyto-toxins at concentrations which reached the IC_{50} level. With treatment C ($4.0Mgha^{-1}$) of *Chromolaena odorata*, 0% germination of soya bean was obtained (Table 3) while treatment D ($8.0Mgha^{-1}$) of *Panicum maximum* similarly produced phyto-toxins which reached the lowest complete inhibition concentration (LCIC) for okra (Table3).

The results suggest the need for caution when using the shoots of both weeds as mulches, especially if okra or soya bean are to be sown, to avoid crop losses. Blum *et al*.[25] reported the content of large amounts of phyto-toxic compounds in the leaves of *Chromolaena odorata* which enable it to retard the growth of other weeds, as well as crop plants, as they decompose. Similarly, Calvert [26] reported the suppression and displacement of local plants by *Panicum maximum* through the production of allelochemicals.

The decomposing mulches of *Cyperus esculentus* appeared to be the most phyto-toxic of the test weed mulches. At $2.0Mgha^{-1}$ (treatment B) the decomposing shoots of the weeds produced allelochemicals which reached the inhibition threshold for all the test seeds, the IC_{50} level for melon and groundnut, and the LCIC for soya bean (Table 3). At $4.0Mgha^{-1}$ (treatment C) of mulch application, the allelochemicals elicited reached the IC_{50} level for maize, okra and cowpea seeds, and the LCIC levels for melon and okra (Table 3). The germination inhibitory effect also tended to increase with increase in mulch levels. Studies by Limore [27] also found that *Cyperus esculentus* elicited phyto-toxins which severely inhibited the growth and yield of cotton, maize, sorghum, groundnut and tobacco.

4. Conclusion

The study has shown that the predominant weeds in the agro ecosystems of the study area accumulated large amounts of phyto-toxic compounds in their tissues and released these into aqueous solutions and into the soil as they decompose. Results revealed that both the water extracts of shoots and roots and decomposing shoot mulches of different weeds showed inhibitory effects on seed germination as well as poor seedling growths of the given crops. This is might be due to the allelopathic effect of these weeds rather than ordinary infertility of the soil. As the problems are most noticeable where cleared vegetation are returned to cultivated fields as decomposing mulches, it would be expedient to review the practice in the light of these finding. However, to confirm the findings, field studies are needed.

Table 1. Germination of seeds (%) as affected by aqueous extracts from shoots and roots of test weeds

Types of extract	Name of weed	Seed germination (%)					
		Maize	Melon	Okra	Cowpea	Soya bean	Groundnut
Aqueous extracts from shoots	*Aspilia africana*	90b*	50b	40c	30d	0e	20c
	Emilia sonchifolia	90b	40c	50b	20e	20c	90b
	Crotalaria retusa	70c	30d	10d	90b	60b	90b
	Chromolaena odorata	40d	10e	10d	40c	10d	90b
	Panicum maximum	30e	10e	10d	10f	10d	10d
	Cyperus esculentus	0f	0f	0e	10f	0e	20c
	Distilled water (control)	100a	100a	100a	100a	100a	100a
Aqueous extracts from roots	*Aspilia africana*	80c*	30d	20c	10d	0d	30d
	Emilia sonchifolia	90b	30c	30c	40b	10c	80b
	Crotalaria retusa	90b	10e	30c	40b	40b	50c
	Chromolaena odorata	90b	30c	60b	50b	20c	90b
	Panicum maximum	80c*	40b	30c	20c	40b	20e
	Cyperus esculentus	10d	0f	0d	0d	0d	0f
	Distilled water (control)	100a	100a	100a	100a	100a	100a

*Means followed by same letter along the columns are not significantly different at 5% level of probability (Duncan multiple range test)

Table 2. Mean germination counts of the seeds (%) as affected by *Aspilia Africana, Emilia sonchifolia* and *Crotalaria retusa* decomposing mulches

Types of extract		Name of weeds					
Types of mulch	Mulch level	Maize	Melon	Okra	Cowpea	Soya bean	Groundnut
Aspilia africana	A	100a*	90a	95a	90a	100a	100a
	B	95a	40b	85a	90a	65b	85a
	C	90a	25c	85a	95a	20d	80a
	D	90a	20c	90a	90a	20d	80a
	E	95a	20c	90a	90a	30c	80a
Emilia sonchifolia	A	100a	95a	100a	95a	100a	90a
	B	85b	65b	55b	85b	75b	90a
	C	75c	55c	40c	75c	85b	90a
	D	75c	55c	40c	85b	80b	75b
	E	40d	30d	10d	85b	80b	80b
Crotalaria retusa	A	100a	100a	100a	100a	100a	100a
	B	100a	50b	55b	85b	75b	85c
	C	85b	15c	30c	90b	55c	80d
	D	90b	15c	10d	90b	55c	90b
	E	90b	15c	10d	90b	30d	90b

*Means followed by same letter along the columns are not significantly different at 5% level of probability (Duncan multiple range test)
Where Treatments (Mulch levels Mgha-1): A = 0, B= 2.0, C = 4.0, D = 8.0 E = 12.0

Table 3. Mean germination counts of the seeds (%) as affected by *Chromolaena odorata* , *Panicum maximum* and *Cyperus esculentus* decomposing mulches

Types of mulch	Mulch level	Maize	Melon	Okra	Cowpea	Soya bean	Groundnut
Chromolaena odorata	A	100a*	100a	100a	95a	100a	100a
	B	85b	65c	35b	100a	25b	85b
	C	85b	75b	15c	100a	0e	85b
	D	65c	30d	15c	75b	0e	65c
	E	30d	5e	5d	60c	5e	30d
Panicum maximum	A	100a	90a	100a	95a	100a	100a
	B	70b	55b	40b	80d	40b	65b
	C	70b	35c	10c	75c	10c	25c
	D	35c	15d	0d	55d	10c	25c
	E	15d	5e	0d	35e	5d	10d
Cyperus esculentus	A	95a	90a	90a	100a	100a	100a
	B	65b	65b	10b	55b	0b	30b
	C	30c	30c	0e	0d	0b	5c
	D	0d	0d	0e	0d	0b	5c
	E	0d	0d	5d	10c	0b	0d

*Means followed by same letter along the columns are not significantly different at 5% level of probability (Duncan multiple range test)
Where Treatments (Mulch levels Mgha-1): A = 0, B= 2.0, C = 4.0, D = 8.0 E = 12.0

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