ALLELOPATHIC EFFECT OF AQUEOUS SHOOT AND ROOT EXTRACTS OF *ALTERNANTHERA BRASILIANA* (L.) O. KUNTZE ON GERMINATION AND SEEDLING GROWTH OF *AMARANTHUS CRUENTUS* L. AND *ZEA MAYS* L.

Oluwakemi Owoseni and Rasheed Olufemi Awodoyin*
Department of Crop Protection and Environmental Biology,
Faculty of Agriculture and Forestry,
University of Ibadan
owoseniolmwakemi@yahoo.com; frawodoyin@gmail.com
**Corresponding Author*

ABSTRACT

Plant species encroachment or invasion is next to deforestation in biodiversity destruction. Invasive plant ousts endemic plant species by competition or/and allelopathy. Alternanthera brasiliana is an invasive weed of the rainforest zone of Southwest Nigeria that is fast spreading and replacing other forbs in the agroecosystem. Understanding the mechanism of its interaction will help in taking decision on its management. This study sought to determine the allelopathic effect of varying concentrations (100, 50, 25, and 12.5%) of aqueous extracts from fresh shoot (S) and root (R) of A. brasiliana on germination and seedling growth of Amaranthus cruentus and Zea mays with the aim of establishing its noxiousness and understand its invasive mechanism.

Effects of varying concentrations on germination of seeds, with water as control, was investigated in petri-dishes in the Ecology Laboratory, Crop Protection and Environmental Biology, University of Ibadan following complete randomized design (CRD) with three replicates. The response of growth of seedlings of the two test crops to the various aqueous extract concentrations were also assessed at the roof top garden and screen house of the Department following CRD in three replicates. One (1) ml of the extract was administered per petri-dish containing 10 seeds of A. cruentus and 2 ml per petri-dish containing 10 seeds of Z. mays. Three hundred (300) ml of extract at varying concentrations was administered per pot of five seedlings of A. cruentus and one seedling of Z. mays. Percentage germination, number of leaves, leaf area, plant height, root length, shoot dry weight and root dry weight of seedlings were measured using standard methods. Data were analyzed by ANOVA and treatments of any parameter with significant means were separated using least significant difference at 5% level of probability.

The varying concentrations of shoot and root had no significant effect on percentage germination in A. cruentus. Germination ranged from 86.7% in Control to 100% in R100 concentrations. At low concentrations of root extract R12.5 and R50, the germination of maize seeds were 76.7% and 86.7% respectively. As the concentration of shoot extract increased, growth of seedlings of A. cruentus and Z. mays increased significantly ($p<0.05$). Compared to control, S100 in A. cruentus increased significantly the number of leaves (13.8 ± 0.7), root length (23 ± 0.7 cm), leaf area (20.6 ± 1.0 cm^2) and shoot dry weight (9.7 ± 0.9g/plant). Also, in Z. mays, S100 significantly ($p<0.05$) increased the shoot dry weight (19.5 ± 0.58 g/plant).

This study showed that interference of Alternanthera brasiliana in the ecosystem may not be by allelopathy. Rather, its aqueous extract enhanced the performance of Amaranthus cruentus and Zea mays. The implication of the study may be that if Alternanthera brasiliana is used as a mulch material, it may not impede germination, but may enhance performance of crop in addition to other benefits of straw mulching.

Keywords: Crop performance; plant interaction; Invasive plants; shoot and root aqueous extracts.

INTRODUCTION

Alternanthera brasiliana (L.) O. Kuntze belongs to the family Amaranthaceae and it is considered to be a weed in the tropics. Sajeev *et al.* (2012) reported that, although *Alternanthera brasiliana* is an ornamental plant, it is now fast spreading as a result of its vegetative growth as both ruderals and agrestals. It is known as Brazilian joy weed, and originates from the tropical and subtropical regions of Australia and South America (Saawan *et al.*, 2011). Species which crossover their natural distribution and get introduced to new habitat are known as alien species (Keane and Crawley, 2002). When alien species increase their spread in the new location to the extent of displacing local biota, they are called invasive species (Mitchell and Power, 2003).

Alternanthera brasiliana has been observed to spread and displace native flora wherever it is growing. Factors that enhance the success of invasive species include the production of large quantity of seeds (Enserink, 1999), their mode of propagation being vegetative and sexual (Silvertown, 2008), strong ability to rapidly colonize an area, which may be due to competition (Funk and Vitousek, 2007), rapid growth rate (Burns, 2006) and production of allelochemicals which deter other plants from establishing in their vicinity (Callaway and Aschelоug, 2000).

Allelopathy is a phenomenon that involves the release of allelochemicals. It is an example of ammensalism interaction in which one of the relating organisms is losing while the other is unaffected (Radosevich *et al.*, 1997). However, it has been redefined as the beneficial or harmful effect of one plant, both crops and weed species, by the release of chemical substance (Han *et al.*, 2008). Aqueous extracts of certain plant species on seed germination, seedling growth and plant biomass of other plants have been reported to exhibit inhibitory and stimulatory effects (Otusanya *et al.*, 2007; Oyerinde *et al.*, 2009). Ratwat *et al.* (2002) reported that water extract of *Helianthus annus* L. inhibited germination of seeds of tobacco (*Nicotiana tabacum* L.), linseed (*Linn usitatissu* L.), mustard (*Brassica juncea* L.) and wheat (*Triticum sp.*). Also, several medicinal plants that produce and store large amounts of secondary metabolites have been reported to have pronounced effect on the growth and distribution of flora in their vicinity (Alagesaboopathi, 2011). Mathela (1994) reported that the secondary metabolites (flavonoids, glycosides, steroids and diterpenoids) of some medicinal plants accounted for their allelopathic activity.

Although *A. brasiliana* has been reported as a medicinal plant (Anonymous, 2005; Macedo *et al.*, 2009), reports on its allelopathic potential are limited. In addition, Lemmens and Horsten (1999) reported that some species of *Alternanthera* are noxious weedsin upland rice, carrot and tomato (*Alternanthera sessilis*), in irrigated rice (*Alternanthera philoxeroides*) and in coffee plantation (*Alternanthera brasiliana*). Recently, it is observed that *Tithonia diversifolia* is fast being replaced by *A. brasiliana* in the fallow and farmlands in Ibadan, Nigeria. This displacement may be as a result of competition or/and allelopathy. Therefore, the objectives of this study are to investigate the allelopathic effects of varying concentrations of aqueous extract of fresh shoot and root of *Alternanthera brasiliana* on the germination of seeds of *Amaranthus cruentus* and *Zea mays* and on the growth of their seedlings.

MATERIALS AND METHODS

The experiment was carried out in the Ecology Laboratory, roof top garden and screen house of the Department of Crop Protection and Environment Biology, University of Ibadan, (Latitude 7°27.047'; Longitude 3°53.832'; elevation 214m asl), Ibadan, Nigeria from December 2012 to March 2013. Ibadan is in the lowland rainforest-savanna transition ecological zone in the Southwestern, Nigeria, with a mosaic vegetation of fire tender trees and secondary grassland (Awodoyin *et al.*, 2007). The soil used for pot experiments was sandy loam, collected in the crop garden of Crop Protection and Environmental protection Biology, University of Ibadan. Seeds of *A. cruentus* and *Z. mays* were obtained from the Institute of Agricultural Research and Training, Moor Plantation, Ibadan. Fresh shoots and roots of *A. brasiliana* were collected from the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan.

The extraction procedure was carried out according to the method of Ahn and Chung (2000) with modification. Instead of 72 g of freshly harvested plant parts being used by the authors, 144 g was used in this study to prepare a stock solution with higher concentration. Shoots and roots of *A. brasiliana* were cut into chips, ground with mortar and pestle, soaked in one litre of distilled water for 12 hours and filtered through cheese cloth and Whatman No.1 filter paper. The final filtrates obtained from each plant part were considered as the stock solution. Other concentrations of the aqueous extract (50%, 25% and 12.5%) were obtained using serial dilution with distilled water (equal V/V). The extracts were stored in the refrigerator at 20°C to prevent putrefaction and degradation of the allelochemicals that may be present in them. The nine treatments were Distilled water (CONTROL), 100% concentration of fresh shoot aqueous extract (S100), 50% concentration of fresh shoot aqueous extract (S50), 25% concentration of fresh shoot aqueous extract (S25),12.5% concentration of fresh shoot aqueous extract (S12.5), 100% concentration of fresh root aqueous extract (R100), 50% concentration of fresh root aqueous extract (R50), 25% concentration of fresh root aqueous extract (R25), 12.5% concentration of fresh root aqueous extract (R12.5).

The seeds of amaranthus and maize were sterilized separately in 5% sodium hypochlorite for 90 seconds to prevent fungi infection, after which they were rinsed for five minutes in running tap water. The seeds were randomly selected and washed thoroughly in distilled water. Fifty four petri-dishes were sterilized using 5% sodium hypochlorite, rinsed thoroughly and lined with Whatman No. 1 filter paper. Nine petri-dishes were in each replicate. Ten seeds of each test crop were placed in each petri-dish. The filter paper in the petri-dishes was replenished with appropriate treatments daily to prevent drying out (2ml for maize and 1ml for amaranthus). The petri-dishes were incubated at room temperature (27°C) for a period of seven days in each experiment. The number of seeds that germinated in each petri-dish was counted and recorded, taking protrusion of plumule as criterion for germination. The germination experiment for each test crop was done in two trials.

For growth experiment, seeds of *A. cruentus* were sown in bags (13 x 9 cm) that contained 4 kg soil, while seeds of *Z. mays* were sown in bags (13x 11 cm) that contained 5 kg soil. Each bag was supplied with 300 ml of water daily for two weeks. At 2 weeks after sowing (WAS) seedlings in each bag for *A. cruentus* were thinned to five seedlings per bag while in maize it was thinned to one seedling per bag. The treatments (300 ml/bag) were applied from 2 WAS, having taken the initial readings on growth parameters. Thereafter, destructive sampling was done randomly at weekly interval from 2 to 6 WAS for *A. cruentus*, while it was 2 to 8 WAS for *Z. mays*.

The growth parameters taken for each test crop were plant height (using meter rule), root length (using meter rule), number of leaves (by visual counting) and leaf area. The leaf area for *A. cruentus* was determined from the formula length x breadth x 0.5 (Otusanya *et al.*, 2007) and that of maize from the formula length x breadth x 0.7 (Elings, 2000). For biomass determination, the plant in each pot was lifted out with the ball of earth and lowered into a bucket of water to loosen the soil so that the root can be fully recovered as much as possible (Awodoyin and Ogunyemi, 2005). Each of the plants was harvested and separated into shoot and root, packaged separately in envelopes, labeled and then oven-dried to constant weight at 80°C in a Gallenkamp oven. The dried plant parts were then weighed on a mettler balance (model P1210) to obtain the dry weight. All experiments were conducted in three replicates. The design for each experiment was completely randomized design (CRD). Treatments in each experiment were statistically compared using ANOVA following SAS (2000). Treatments of parameters with significantly different means were separated using least significant difference (LSD $p<0.05$).

Table 1: Effect of varying concentrations of shoot and root aqueous extracts of *A. brasiliana* on germination of seeds of *Amaranthus cruentus* and *Zea mays* in Ibadan, Nigeria

Treatments	% Germination			
	Amaranthus cruentus		*Zea mays*	
	Trial 1	Trial 2	Trial 1	Trial 2
CONTROL	---	93.3 ± 0.82	96.7 ± 0.41	100.0 ± 0.00
S12.5	90.0 ± 1.22	90.0 ± 0.71	90.0 ± 0.41	90.0 ± 0.00
S25	90.0 ± 0.71	70.0 ± 1.87	93.3 ± 0.41	96.7 ± 0.41
S50	100.0 ± 0.00	86.7 ± 0.82	90.0 ± 0.71	96.7 ± 0.41
S100	96.7 ± 0.41	86.7 ± 1.08	96.7 ± 0.41	93.3 ± 0.41
R12.5	86.7 ± 0.41	96.7 ± 0.41	76.7 ± 1.08	90.0 ± 0.00
R25	93.3 ± 0.82	90.0 ± 0.71	93.3 ± 0.82	96.7 ± 0.41
R50	90.0 ± 0.71	90.0 ± 0.71	96.7 ± 0.41	86.7 ± 0.41
R100	100.0 ± 0.00	93.3 ± 0.82	96.7 ± 0.41	96.7 ± 0.41
LSD p<0.05	NS	NS	4.8	8.1

Table 2: Effect of varying concentrations of shoot and root aqueous extracts of *Alternanthera brasiliana* on number of leaves and leaf area (cm^2/plant) of *Amaranthus cruentus* at 6WAS and *Zea mays* at 8 WAS in Ibadan, Nigeria

TREATMENTS	*Amaranthus cruentus*		*Zea mays*	
	Number of Leaves	Leaf area	Number of Leaves	Leaf area
CONTROL	13.1 ± 0.6	9.5 ± 0.8	16.0 ± 0.7	215.0 ± 20.0
S12.5	14.3 ± 0.2	10.8 ± 0.7	14.3 ± 0.8	203.9 ± 9.7
S25	13.3 ± 0.4	13.1 ± 1.2	14.3 ± 0.4	211.7 ± 24.0
S50	13.3 ± 1.2	13.3 ± 1.7	14 ± 0.0	239.8 ± 12.7
S100	13.6 ± 0.2	20.6 ± 1.0	16.3 ± 0.8	242.5 ± 27.7
R12.5	13.0 ± 0.5	12.2 ± 0.7	12.3 ± 0.8	216.1 ± 25.2
R25	11.5 ± 0.4	9.7 ± 1.1	13.6 ± 0.8	215.9 ± 11.0
R50	13.3 ± 0.7	9.1 ± 1.2	16.0 ± 0.7	199.9 ± 18.9
R100	13.7 ± 0.9	9.1 ± 0.5	15.7 ± 0.4	278.0 ± 10.6
LSD p<0.05	NS	3.1	1.6	45.9

Table 3: Effect of varying concentrations of shoot and root aqueous extracts of *Alternanthera brasiliana* plant height (cm/plant) and root length (cm/plant) of *Amaranthus cruentus* at 6WAS and *Zea mays* at 8 WAS in Ibadan, Nigeria

TREATMENTS	*Amaranthus cruentus*		*Zea mays*	
	Plant Height	Root length	Plant Height	Root length
CONTROL	39.2 ± 1.5	18.4 ± 1.8	121.7 ± 35.7	80.7 ± 18.5
S12.5	35.8 ± 2.4	20.3 ± 1.1	135.5 ± 5.1	74.0 ± 28.0
S25	40.2 ± 1.1	20.8 ± 1.0	144 ± 10.2	54.7 ± 2.9
S50	37.4 ± 1.9	20.9 ± 1.0	126.5 ± 7.6	71.3 ± 11.9
S100	41.7 ± 1.5	23.0 ± 0.7	155.3 ± 14.5	51.0 ± 0.9
R12.5	33.2 ± 0.6	18.2 ± 0.4	135 ± 1.6	59.3 ± 6.4
R25	29.1 ± 1.6	15.8 ± 0.7	144.8 ± 2.9	54.7 ± 1.5
R50	32.7 ± 3.0	21.3 ± 0.7	143.7 ± 3.9	57.3 ± 2.3
R100	36.7 ± 0.9	22.3 ± 2.3	150.5 ± 4.6	69.0 ± 12.6
LSD p<0.05	5.2	3.7	NS	NS

Table 4: Effect of varying concentrations of shoot and root aqueous extracts of *Alternanthera brasiliana* shoot dry weight (g/plant) and root dry weight (g/plant) of *Amaranthus cruentus* at 6WAS and *Zea mays* at 8 WAS in Ibadan, Nigeria

TREATMENTS	*Amaranthus cruentus*		*Zea mays*	
	Shoot dry weight	**Root dry weight**	**Shoot dry weight**	**Root dry weight**
CONTROL	6.5 ± 0.7	1.4 ± 0.1	13.4 ± 1.43	1.56 ± 0.28
S12.5	6.8 ± 0.3	1.4 ± 0.2	15.7 ± 1.57	1.16 ± 0.14
S25	7.0 ± 0.6	1.2 ± 0.0	14.5 ± 0.60	1.1 ± 0.07
S50	6.6 ± 0.9	1.5 ± 0.1	16.8 ± 1.07	2.08 ± 0.66
S100	9.7 ± 0.9	2.3 ± 0.2	19.5 ± 0.58	1.93 ± 0.18
R12.5	7.4 ± 0.7	1.1 ± 0.1	11.0 ± 0.94	0.81 ± 0.18
R25	5.7 ± 1.3	1.2 ± 0.1	14.4 ± 0.58	1.83 ± 0.39
R50	5.7 ± 0.5	1.0 ± 0.2	12.8 ± 0.56	1.29 ± 0.41
R100	5.3 ± 0.3	1.3 ± 0.6	16.5 ± 0.69	1.67 ± 0.03
LSD p<0.05	**2.1**	**0.4**	**2.7**	**NS**

RESULTS

The mean percentage germination in *A. cruentus* ranged from 86.7 to 100% in the first trial and 70 to 96.7% in the second trial (Table 1). There was no significant difference between control and the varying concentrations of fresh shoot and root extracts of *A. brasiliana* in the two trials. In *Z. mays*, germination ranged from 76.7 to 96.7% in the first trial and from 86.7 to 96.7% in the second trial. Control (96.7 ± 0.41% - 1st trial and 100.0 ± 0.00% - 2nd trial) was significantly greater than S12.5 (90.0% in the 2 trials) and R12.5 (76.7% - 1st trial and 90.0% - 2nd trial) (Table1).

Effect of varying concentrations of aqueous extracts on growth and biomass accumulation

Number of leaves (NL)

At 6 WAS the NL of *A. cruentus* ranged between 11.5 in R25 to 14.3 in S12.5 (Table 2). Generally, the NL was more in extract treatments than Control, except R12.5 and R25. The NL was less in root extracts than shoot extracts, but the treatments were not significantly different.

At 8 WAS the NL of maize was reduced by both the shoot and root extracts with the number ranging from 14 to 16.3 in shoot extract and 12.3 to 16.0 in root extract (Table 2). The S12.5, S25, S50, R12.5, R25 and R100 were significantly less than Control with regards to NL.

Leaf Area

The leaf area of *A. cruentus* ranged from 9.1 cm²/plant in R100 to 20.6 cm²/plant in S100 (Table 2). The leaf area increased as the concentrations of shoot extract increased but conversely decreased as the concentrations of root extract increased. The S25 (13.1 cm²/plant), S50 (13.3 cm²/plant) and S100 (20.6 cm²/plant) were significantly ($p<0.05$) greater than Control (9.5 cm²/plant). All other treatments and Control were not significantly different.

In maize, the leaf area per plant for S50 (239.8 cm²/plant), S100 (242.5 cm²/plant) and R100 (278.0 cm²/plant) were greater than Control (215.0 cm²/plant), though only R100 was significantly different (Table 2).

Plant Height

The root extracts at low concentrations (R12.5 to R50) significantly suppressed height growth compared to Control while shoot extracts enhanced the growth, though not significantly different from Control (Table 3). *Amaranthus cruentus* plants given S100 were the tallest (41.7 cm), though not significantly taller than Control (39.2 cm). However, the plants given R25 were significantly shorter (29.1 cm) than Control.

The plant height of maize compared to Control (121.7 cm) was increased by the shoot and root extracts, though the mean height values were not significantly different. In the shoot extract the mean height varied from 126.5 cm in S50 to 155.3 cm in S100, while in the root extract the mean height ranged from 135.0 cm in R12.5 to 150.5 cm in R100 (Table 3).

Root Length

In *A. cruentus* the root length increased as the concentrations of shoot extract increased. However, the root extracts did not follow a specific trend. The plants given S100 had significantly ($p<0.05$) longer roots (23 cm) than Control (18.4 cm) (Table 3).

In maize, both shoot and root extracts reduced root length compared to control (80.7 cm) at 8 WAS. For shoot extract the root length ranged from 54.7 cm in R12.5 to 69.0 cm in R100. The extract concentrations and Control were not significantly different with regards to root length.

Shoot Dry Weight

For *A. cruentus* the shoot dry weight at 6 WAS varied from 5.3 g/plant in R100 to 9.7 g/plant in S100 (Table 4). The shoot dry weight increased with increasing shoot extract concentrations but decreased with increasing root extract concentrations. Only S100 (9.7 g/plant) was significantly ($p<0.05$) higher than Control (6.5 g/plant) with regards to shoot dry weight. All other treatments and Control were not significantly different.

The shoot dry weight of *Z. mays* plants that received shoot extract treatments ranged from 14.5 g/plant in S25 to 19.5 g/plant in S100, while in those that received root extract treatments the shoot dry weight ranged from 11.0 g/plant in R12.5 to 16.5 g/plant in R100 (Table 4). Generally, the shoot dry weight increased with increasing concentrations in both shoot and root extracts. With regards to shoot dry weight S50, S100 and R100 concentrations were significantly ($p<0.05$) higher than the Control while others were not significantly different.

Root Dry Weight

For *A. cruentus* the root dry weight varied from 1.0 g/plant in R50 to 2.3 g/plant in S100. Only S100 (2.3 g/plant) was significantly ($p<0.05$) higher than Control (1.4 g/plant). Other treatments and Control were not significantly different (Table 4).

The root dry weight of *Z. mays* plants that received shoot extract treatments ranged from 1.1 g/plant in S25 to 2.08 g/plant in S50. However, those that received root extract had their root dry weight ranging from 0.81 g/plant in R12.5 to 1.83 g/plant in R25. Compared to Control (1.56 g/plant) the concentrations were not significantly different (Table 4).

DISCUSSION

The result obtained from the study revealed that in the germination experiment, application of aqueous extract of *Alternanthera brasiliana* on *Amaranthus cruentus* had no significant effect. However, in maize while root extract at low concentration (R12.5) significantly suppressed germination in the first trial, it was not significant in the second trial. Though Fujil *et al.* (1992) reported that allelopathy has ability to reduce or cause depression in the germination of seeds, the extracts of *A. brasiliana* did not in this study. This result is in agreement with Sangakkara *et al.* (2003) who found that *Tithonia diversifolia* did not suppress germination in maize.

On the other hand, shoot extract of *A. brasiliana* stimulated seedling growth of *A. cruentus* and *Z. mays*. Result indicated a better performance of *A. cruentus* at 6 WAS and *Z. mays* at 8 WAS in the shoot extract at higher concentration (S100) than in Control. This may indicate that shoot extract of *A. brasiliana* at high concentration (S100) stimulated the growth. The results of this study agree with Oudhia *et al.* (1997) who reported that leachate of *Blumeral arcera* L. promoted seedling vigourin wheat (*Triticum sp.*) and germination was not affected. However, the results are in contrast to the report of Otusanya *et al.* (2007) that aqueous and shoot extracts of *T. diversifolia* was inhibitory to the germination and growth of *Amaranthus cruentus*.

The shoot extract at high concentration (S100) stimulated better dry matter accumulation in *Z. mays* and *A. cruentus* seedlings than Control. This conforms to the findings of Oyerinde *et al.* (2009) who reported that aqueous extract of *T. diversifolia* stimulated growth of *Z. mays*. Also, Oudhia (2001) reported positive allelopathic effects of *Parthenium* leaf extract on wheat.

The enhanced growth of seedlings of *A. cruentus* and *Z. mays* by the shoot extract of *A. brasiliana* at high concentration (S100) revealed that *A. brasiliana* is allelopathic, but stimulatory rather than inhibitory. This indicates that the spread of *A. brasiliana* in the ecosystem is not as a result of allelopathic displacement of other plant species. It may be as a result of attributes like its extensive root system, vegetative mode of propagation (Sajeev*et al.*, 2012), perennial life cycle, or ability of *A. brasiliana* to withstand trimming according to Lemmens and Horsten (1999).Perenniality assists *A. brasiliana* to survive dry season. This may help the plant to dominate a habitat and to fully establish, giving little room for the indigenous species, and even other invasive alien species, that are annuals to establish in another season.

The study also reveals that shoot of *Alternanthera brasiliana* may be used as mulch in the production of *A. cruentus* and *Z. mays*. The leachate from its decomposition may also be used as a biofertilizer which is in accordance with Sangakkara *et al.* (2003) who reported in their investigation that *T. diversifolia* is a potential green manure and organic fertilizer for vegetable crops. This is further corroborated by Otusanya *et al.* (2007) who reported the stimulatory effect of *T. diversifolia* on the germination and growth of *Oryza sativa*.

This study showed that interference of *Alternanthera brasiliana* in the ecosystem may not be by allelopathy. Rather, its aqueous extract enhanced the performance of *Amaranthu scruentus* and *Zea mays*. The implication of the study may be that if *Alternantherabrasiliana* is used as a mulch material, it may not impede germination, but may enhance performance of crop.

REFERENCES

Ahn, J.K. and Chung M. (2000). Allelopathic potential of rice hulls on germination and Seedling growth of Barnyeard grass. *Agronomy Journal* 92:1162-1167.

Alagesaboopathi, C. (2011). Allelopathic Effects of *Andrographis paniculata* Nees on Germination of *Sesamum indicum*. L. *Asian J. Exp. Biol. Sci. 2 (1): 147-150.*

Anonymous (2005). Raw Materials, Council of Scientific & Industrial Research. *The Wealth of India* New Delhi, 206-207.

Awodoyin, R.O. and Sola Ogunyemi (2005). Stocking density effect on the performance and weed smothering ability of an annual legume, *Senna obtusifolia* (L.) Irwin and Berneby. *Ibadan Journal of Agricultural Research (An International Journal)* 1(1): 30-38.

Awodoyin, R.O., Ogbeide, F.I. and Oluwole, O. (2007). Effects of three mulch types on the Growth and yield of tomato (*Lycopersicone sculentum*M.) and weed suppression in Ibadan a rain forest- savanna transition zone of Nigeria. *Tropical Agricultural research and Extension* 10: 53-60.

Burns, J.H. (2006). Relatedness and environment affect traits associated with invasive and noninvasive introduced Commelinaceae. *Ecological Applications* 16: 1367-1376.

Callaway, R.M. and Aschehoug, E.T. (2000). Invasive plants versus their new and old neighbors: a mechanism for exotic invasion. *Science* 290: 521 - 523.

Elings, A. (2000). Estimation of leaf area in Tropical Maize. *Agronomy Journal* 92: 436-444.

Enserink, M. (1999). Biological invaders sweep in. *Science* 285: 1834 - 1836.

Fujil, Y., Shibuya, T. and Yasuda, T. (1992). Allelopathy of velvet bean: It's discriminate and identification of L- Dopa as a candidate of allelopathic substances. *Japan Agricultural Research Quarterly* 25:238-247.

Funk, J. L. and Vitousek, P.M. (2007). Resource-use efficiency and plant invasion in low-resource systems. *Nature* 446: 1079-1081.

Han, C.M., Pan,K.W., Wu, N., Wang, J.C and Li, W. (2008). Allelopathic effect of ginger on seed germination and seedling growth of soybean and chive. *Sci. Hortc.* 116:330-336.

Keane, R.M. and Crawley, M.J. (2002). Exotic plant invasions and the enemy release hypothesis *Trends Ecol. Evol.* 17: 164 -170.

Lemmens, R.H.M.J. and Horsten, S.F.A.J. (1999). *Alternanthera* Forssk.In: de Padua, L.S Bunyapraphatsara, N. and Lemmens, R.H.M.J. (Editors). Plant Resources of South-East Asia. *Medicinal and poisonous plants* 12(1): 105-109.

Macedo A.F., Lage, C.L., Esquibel, M.A., de Souza, M. M., da Silva, K. L., Niero, R. and Cechinel- Filho, V. (2009). *Acta Farm. Bonaerense.*, 23 (4): 515-519.

Mathela, C.S. (1994). Allelochemicals in Medicinal and Aromatic Plants. In: Agriculture and Forestry Narwal, S.S. and Tauro, P. (eds). *Scientific Publishers, Jodhpur*, India. pp. 213-228.

Mitchell, C.E. and Power, A.G. (2003). Release of invasive plants from fungal and viral pathogens. *Nature* 421: 625 - 627.

Otusanya, O.O, Adelusi, A.A and Ilori, J.A. (2007). Phytotoxicity effect of *Tithonia diversifolia* on germination and growth of rice. *Research Journal of Botany* 2(1):23-32.

Oudhia, P., Kolhe, S.S and Tripathi,R.S. (1997). Allelopathic effect of *Blumea lacera* L. on chick pea and rabi weeds. *Agric. Sci. Digest* 17 (4):275-278.

Oudhia, P. (2001). Germination and seedling vigour of wheat as affected by allelopathy of some obnoxious weeds *Agric. Sci. Digest*, 21 (4) : 275 - 276,

Oyerinde, R.O, Otusanya, O.O and Akpor, O.B. (2009). Allellopathic effect of *Tithonia diversifolia* on the germination, growth and chlorophyll contents of maize (*Zea mays* L.) *Scientific research and Essay* 4 (12):1553-1558.

Radosevich, S.R., Holt,J.S. and Ghersa, C.M. (1997). Weed Ecology Implications of Management. 2nd Johnwiley and Sons, Inc. New York, 589pp.

Ratwat,L.S, D.S.K Ratwat,S.S.Narwal, R. Palaniraj and S.C Sati (2002) Allelopathic effects of aqueous extracts of sunflower (*Helianthus annus* L) root on some winter oil seed crop. *Geobies (jodhpur)* 29: 225-228.

Saawan Kumar, Pradeep Singh, Garima Mishra, Saurabh Srivastav1, Jha, K. K. andKhosa, R.L. (2011). Phytopharmacological review of *Alternanthera brasiliana.Asian Journal of Plant Science and Research* 1 (1): 41-47.

Sajeev, T.V., Sankaran, K.V. and Suresh, T.A. (2012). Are Alien Invasive Plants a Threat to Forests of Kerala? *KFRI Occasional Papers* 001.

Sangakkara, U.R, Richner W., Schneider M.K, Stamp P. (2003). Impact of intercropping beans (*Phaseolus vulgaris*) and sunhemp (*Cotalaria juncea*) on growth, yields and nitrogen uptake of maize (*Zea mays*) grown in the humid tropics during the minor rainy season. *Maydica* 48: 233 – 239.

Silvertown, J. (2008). The evolutionary maintenance of sexual reproduction: evidence from the ecological distribution of asexual reproduction in clonal plants . *International Journal of Plant Sciences* 169: 157–168.