COMPARATIVE ALLELOPATHIC POTENTIAL OF METABOLITES OF TWO *Alternanthera* SPECIES AGAINST GERMINATION AND SEEDLING GROWTH OF RICE[1]

Análise Comparativa do Potencial Alelopático de Dois Metabólitos da Espécie **Alternanthera** *em Relação à Germinação e ao Crescimento de Plântulas de Arroz*

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ABSTRACT - A laboratory study was conducted to investigate the allelopathic effect of aqueous extracts of plant parts of *Alternanthera philoxeroides* and *A. sessilis* and soil incorporated residues on germination and seedling growth of rice (*Oryza sativa*). Aqueous extracts prepared from different plant parts of *Alternanthera* species delayed rice germination. *Alternanthera philoxeroides* and *A. sessilis* inhibited rice germination by 9-100% and 4-49%, respectively. Germination of rice seeds was reduced with increasing concentration of aqueous leaf extracts of both weed species. Early seedling growth (root and shoot lengths) and seedling vigor index were significantly reduced by 5% aqueous leaf extract compared with distilled water treated control. Germination, root and shoot lengths, root and shoot dry weights and seedling vigor index of rice were drastically reduced by 3 and 4% in residue infested soil compared with residue free soil. The inhibitory effect of *A. philoxeroides* in terms of germination and seedling growth of rice was greater than that of *A. sessilis.* Five percent aqueous leaf extract and 4% residue infested soil of *A. philoxeroides* caused complete failure of rice seed germination. *Alternanthera philoxeroides* contained water soluble phenolics, namely 4 hydroxy-3-methoxy benzoic acid (16.19 mg L^{-1}) and m-coumaric acid (1.48 mg L^{-1}), whereas *Alternanthera sessilis* was rich in chlorogenic acid (17.85 mg L^{-1}), gallic acid (11.03 mg L^{-1}) and vanillic acid (9.88 mg L^{-1}). The study indicates that the allelopathic potential of *Alternanthera* species may play an important role in enhancing the invasiveness of these species and may suppress rice plants in the vicinity.

Keywords: allelopathy, *Alternanthera*, rice, germination/seedling growth.

RESUMO - Foi realizado um estudo laboratorial para investigar o efeito alelopático de extratos aquosos de partes de plantas de ***Alternanthera philoxeroides*** *e* ***A. sessilis*** *e dos resíduos incorporados ao solo na germinação e no crescimento de plântulas de arroz (****Oryza sativa****). Os extratos aquosos preparados a partir de diferentes partes das plantas das duas espécies de* ***Alternanthera*** *retardaram a germinação do arroz.* ***Alternanthera philoxeroides*** *e* ***A. sessilis*** *inibiram a germinação de arroz em 9-100 % e 4-49 %, respectivamente. A germinação de sementes de arroz foi reduzida com o aumento da concentração de extratos aquosos de folhas de ambas as espécies de plantas daninhas. O crescimento inicial de plântulas (comprimento da raíz e da parte aérea) e o índice de vigor sofreram uma redução significativa pelo extrato aquoso a 5% em comparação com o controle de água tratada destilada. Os comprimentos de germinação, raiz e parte aérea, a massa seca da raiz e da parte aérea, e o índice de vigor de plântulas de arroz foram drasticamente reduzidos em 3 e 4% em solo infestado por resíduos em comparação com solo livre de resíduos. O efeito inibitório de* ***A. philoxeroides*** *em termos de germinação e crescimento das plântulas de arroz foi maior do que o efeito de* ***A. sessilis****. O extrato aquoso a 5% e o solo infestado de resíduos de* ***A. philoxeroides*** *a 4% causaram a falha completa da germinação das sementes de arroz.* ***Alternanthera*** *philoxeroides continha compostos fenólicos solúveis em água, ou seja, ácido 4-hidroxi-3-metoxi-benzoico (16,19 mg L^{-1}) e ácido m cumárico (1,48 mg L^{-1}), enquanto que* ***Alternanthera sessilis*** *continha uma grande quantidade de ácido*

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clorogênico (17,85 mg L^{-1}), ácido gálico (11,03 mg L^{-1}) e ácido vanílico (9,88 mg L^{-1}). O estudo indica que o potencial alelopático de espécies de ***Alternanthera*** *pode desempenhar um papel importante no aumento da capacidade de invasão dessas espécies, as quais podem suprimir as plantas de arroz nas imediações.*

Palavras-chave: alelopatia, *Alternanthera*, arroz, germinação/crescimento de plântulas.

INTRODUCTION

Alternanthera species are invasive aquatic weeds posing a strong threat to agro-biodiversity in several countries in the world. Weeds are a continuous and ubiquitous threat *to* agricultural productivity (Riaz et al., 2009). Weeds limit growth and yield of crops by competing for available moisture, nutrients, light, space and air; and releasing phytotoxic compounds in their environment (Zimdahl, 2007). Weeds influence crop plants by releasing phytotoxins which are present in their seeds, decomposing residues, leachates, exudates and volatiles (Narwal, 2004).

The allelopathic effect of a weed on a crop can be ascertained by reduced germination and growth of the latter, a technique known as plant bioassay. The extent of allelopathic inhibition on germination and seedling growth of crops varies from weed species to weed species (Hamayun et al., 2005) and its plant parts (Economou et al., 2002; Aziz et al., 2008). Most weed species have inhibitory effects on crops; yet some weed species also exhibit stimulatory effects (Kadioglu et al., 2005).

The mechanism of allelopathic suppression by weeds is complex, as it involves interactions of different classes of chemicals such as flavonoids, alkaloids, steroids, terpenoids, phenolic compounds and amino acids. Since the majority of these compounds have phytotoxic properties, their overall effect is inhibitory on germination and growth of crop plants (Bensal et al., 1992; Prasad and Subhashini, 1994).

Rice is an important staple food and cash crop in different countries in the world. It is estimated that weed-induced average crop losses are 9.5% worldwide (Alam, 2003). In severe cases, yield losses may be more than 50%, depending on density, species, time of weed germination, duration of weed infestation, space available for growth and other management practices (BRRI, 2006). Two emerging invasive rice weeds are *A. sessilis* and *A. philoxeroides*, which seem to be more proliferating and problematic than conventional weeds. Liu-qing et al. (2007) observed that *A. philoxeroides* reduced grain yield of rice by 43-50%. *Alternanthera philoxeroides* and *A. sessilis* are commonly known as alligator weed and sessile joyweed, respectively, which belong to the family Amaranthaceae. Alligator weed is a perennial, emergent, semi aquatic species that rarely sets seeds (Julien, 1995). Alligator weed has the potential to devastate natural systems, agricultural areas, and recreational areas because it is easily spread by human activities. It is competitive with other plant species, forms monocultures, and is not constrained by natural enemies or other environmental constraints that exist in its native range (Bassett, 2009). It is a problematic weed in 30 countries; it is considered a serious weed in eight of these and a major weed in the others (Gunasekera and Bonila, 2001). Alligator weed has been recognized as an invasive and troublesome weed in rice, corn, cotton, and soybean in China (Lu et al., 2002, Ye et al., 2003). In China, crop yield was reported to be reduced by 20-63 percent due to alligator weed (Ensbey, 2001). Sessile joyweed occurs in both wetlands and uplands and can grow in a variety of soil types. The allelopathic potential of *A. philoxeroides* in its successful invasion of new areas has been reported by Jinrong et al. (2006) and Xie et al. (2010). Paria and Mukharjee (1981) and Liu-qing et al. (2007) have reported inhibitory effect of *A. philoxeroides* on mustard and rice, and lettuce, respectively. The detrimental effect of *A. riandra* on germination and early seedling growth of soybean, groundnut and green gram was reported by Tiwari et al. (1985). This literature shows that little information is available about the allelopathic effects of *Alternanthera* species on germination and seedling growth of crops. No information is available about the comparative allelopathic potential of *A. philoxeroides* and *A. sessilis* on rice. It is hypothesized that *Alternanthera* residues may hamper the germination and growth of rice plants by releasing water soluble allelochemicals. The objective of the study was to assess the phytotoxicity of two *Alternanthera* species as for germination and early seedling growth of rice.

MATERIALS AND METHODS

Collection of plant materials

Fully grown plants of *A. philoxeroides* and *A. sessilis* from an infested area were collected. These were separated into root, shoot, leaf, flower only in (*A. sessilis*) and whole plant fractions. These plant parts were cut into small pieces (2-3 cm) with scissors and air dried for a month under shade. The dried plant fractions were stored in plastic bags at room temperature before use in the experiments. For bioassay studies, certified seeds of rice variety "Basmati-515" were used.

Preparation of aqueous extracts of *Alternanthera* species

The various plant parts of both species were soaked separately in distilled water (1:20 w/v) for 24 hours at room temperature. The water extract of each plant fraction was filtered through a sieve to separate solid materials. The extract was then filtered through filter paper. The different extracts, each designated as 5%, were labeled and stored in bottles for further use.

In order to study the effect of residues of *Alternanthera* species on germination and early seedling growth of rice, soil was collected from a profile of 0 to 25 cm in an area previously non-infested by *Alternanthera* species. Soil was air dried, sieved and stored in plastic bags at room temperature. The soil was sandy loam. In a preliminary study, leaf aqueous extracts of *Alternanthera* species showed a greater inhibitory effect on rice seed germination. These extracts were further diluted with distilled water to get concentrations of 1, 2, 3, and 4%.

Treatments and experimental design

There were six treatments for germination bioassay with aqueous extracts for *A. sessilis* and five treatments for *A. philoxeroides* because later species does not produce flowers. There were five treatments for germination bioassay with residue amended soil (both species). The treatments were arranged in a completely randomized design with four replications for each experiment conducted at maximum temperature of 34 ^oC and minimum temperature of 27 ^oC.

The details of the different experiments are given below.

- Germination bioassay with aqueous extracts of plant parts of *Alternanthera* species

The effects of root, shoot, leaf, flower (*A. sessilis*) only and whole plant aqueous extracts (5%) of *Alternanthera* species were studied on the germination of rice in a laboratory bioassay in order to determine the allelopathic potential of *Alternanthera* species. In each treatment, 25 rice seeds were placed in 9 cm diameter petri dishes separately lined with Whatman no. 42 filter paper moistened with 4 mL of distilled water as control and water extracts, according to the nature of treatments.

- Dose-response germination bioassay with aqueous leaf extract

In a preliminary screening, it was found that experiments with leaf extracts of *A. philoxeroides* and *A. sessilis* had the strongest inhibitory effect on seed germination; thus, their leaves were selected for another study. The effects of different concentrations of *A. philoxeroides* and *A. sessilis* leaves (i.e., 1, 2, 3, and 4 percent) on seed germination and early growth of rice were separately studied for each weed species. Twenty five seeds of rice were placed in a 9 cm diameter petri dish lined with a Whatman no. 42 filter paper moistened with the respective treatment concentration of *A. sessilis* and *A. philoxeroides* leaf extract.

- Seedling emergence and growth bioassay with *Alternanthera* residue amended soil

Under natural field conditions, residues of weed species fall on the soil surface and get mixed into the soil with subsequent tillage practices. In order to simulate these natural conditions, 6, 12, 18, 24 and 30 g of *A. philoxeroides* and *A. sessilis* residues were added and mixed to 600 g of soil so as to get 1, 2, 3, 4, and 5% concentration respectively, for each *Alternanthera* species separately. Then, 200 mL of distilled water was added to each pot and each pot was kept at room temperature for 15 days. As a control, 600 g of unmodified soil was soaked in 200 mL of water for 15 days. Ten seeds of rice were sown in plastic pots measuring 10 cm in diameter and 10 cm in depth filled with amended soil. All the pots were placed on a laboratory bench at maximum of 36 °C and minimum of 32 °C. Each pot was watered with 30 mL of water daily.

Data collection and statistical analysis

Mean Germination Time (MGT) was calculated as per the equation of Ellis and Roberts (1981).

$$MGT = \Sigma Dn/\Sigma n$$

where n is the number of seeds that had germinated on day D and D is the number of days counted from the beginning of germination.

Time taken to 50% germination (T50) was calculated by using the formula given by Coolbear et al. (1984) as modified by Farooq et al. (2004).

$$T_{50} = \frac{ti + (N/2 - ni)(tj - ti)}{(nj - ni)}$$

where *N* is the final number of germinated seeds while *nj* and *ni* are the cumulative number of seeds germinated by adjacent counts at times *tj* and *ti*, respectively, where $ni < N/2 < nj$. Germination index (GI) was calculated as given by the Association of Official Seed Analysis (1990). Germination was calculated by counting and removing the germinated seeds. Germination was observed daily in accordance with the methods of the Association of Official Seed Analysis (1990).

Total soluble phenolics were determined as described by Randhir and Shetty (2005) and were expressed as gallic acid equivalents (Table 6). For identification and quantification of their suspected phytotoxins, aqueous extracts were chemically analyzed (Table 5) on Shimadzu HPLC system (Model SCL-10A, Tokyo, Japan). The peaks were detected by UV detector. Standards of suspected phytotoxins (Aldrich, St Louis, USA) were run similarly for their identification and quantification. Concentration of each isolated compound was determined by the following equation: Concentration (ppm) = Area of the sample/Area of the standadrd × Concentration of the standard × Dilution factor.

Seedling vigor index (SVI) was calculated by using the following formula of Abdul-baki & Anderson (1973).

SVI = germination/emergence% × radicle length.

Each experiment was repeated twice. The average data obtained from each experiment were subjected to analysis of variance using computer software Statistix 8.1. Analysis of variance of all the data was conducted. The treatment means were grouped on the basis of the least significant difference at the 0.05 level of probability (Steel et al., 1997).

RESULTS AND DISCUSSION

Table 1 shows that aqueous extracts of different plant parts of *A. philoxeroiodes* and *A. sessilis* significantly affected the time taken to 50% seed germination (T50) and mean germination time (MGT). Both were significantly increased in comparison with the distilled water control. The root aqueous extract and the stem aqueous extract of *A. sessilis* and *A. philoxeroides*, respectively, proved to be more stimulatory to T50 and MGT than the control. Maximum germination index (GI) was recorded in the control, which was significantly higher than all other treatments. The minimum value for GI was recorded with leaf extract and whole plant extract of *A. sessilis* and *A. philoxeroides*, respectively. T50 and MGT taken by rice seeds to germinate were significantly reduced with an increase in the aqueous leaf extract concentration of *A. sessilis* and *A. philoxeroides* .

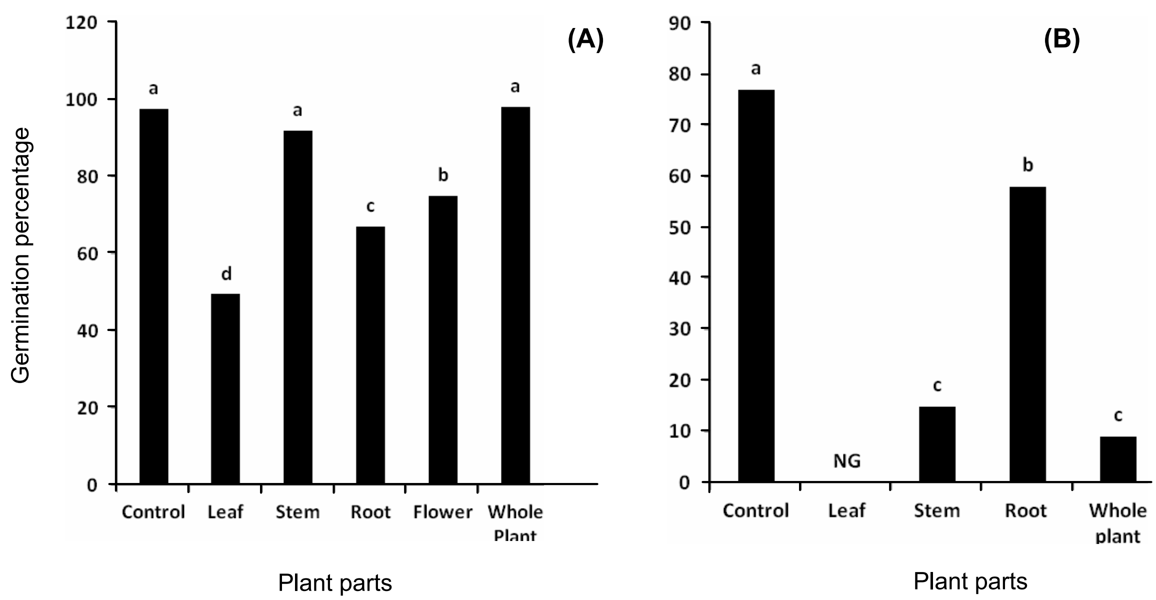
More delay in seed germination with root extract of *A. sessilis* and stem extract of *A. philoxeroides* compared with other plant part extracts indicate differential inhibitory effect of plant parts of *Alternanthera* species. Increase in germination time and decrease in germination index of rice by aqueous extracts of plant parts of *A. sessilis* and *A. philoxeroides* are supported by Kadioglue et al. (2005) and Tanveer et al. (2008 and 2010). They reported inhibition of the germination rate of different crops with different plant part extracts.

As compared to the distilled water control (0%), the aqueous extract of *A. philoxeroides* and *A. sessilis* from flower, leaf, stem, root parts and whole plant each at 5% concentration level exhibited significant (p>0.05) inhibition of seed germination of rice (Figure 1).

Table 1 - Germination and seedling vigor traits of rice as influenced by aqueous extracts of various plant parts of *A. sessilis and A. philoxeroides*

Plant parts	*A. sessilis*			*A. philoxeroides*		
	T50 (days)	MGT (days)	GI	T50 (days)	MGT (days)	GI
Control	1.98 e	2.63 e	9.73 a	2.27 c	2.73 d	7.30 a
Leaf extract	5.26 b	5.74 b	2.67 d	NG	NG	NG
Stem extract	4.03 c	5.16 c	5.17 c	7.81 a	9.48 a	0.45 c
Root extract	5.99 a	6.24 a	3.31d	4.55 b	5.17 c	2.90 b
Flower extract	3.14 d	3.70 d	5.52 c	-	-	-
Whole plant extract	3.41 cd	3.88 d	6.90 b	7.06 a	7.83 b	0.35 c
LSD ≤ 0.05	0.682	0.446	0.661	1.113	0.295	0.469

Means sharing the same letters in a column do not differ significantly at 0.05 probability. Level according to the Least Significance Difference test (LSD).



Bars of treatments having letters in common do not differ significantly at the 5% probability level according to the Least Significance Difference test (LSD). NG = Not germinated.

Figure 1 - Germination percentage of rice as influenced by aqueous extracts of various plant parts of (A) *A. sessilis and* (B) *A. philoxeroides.*

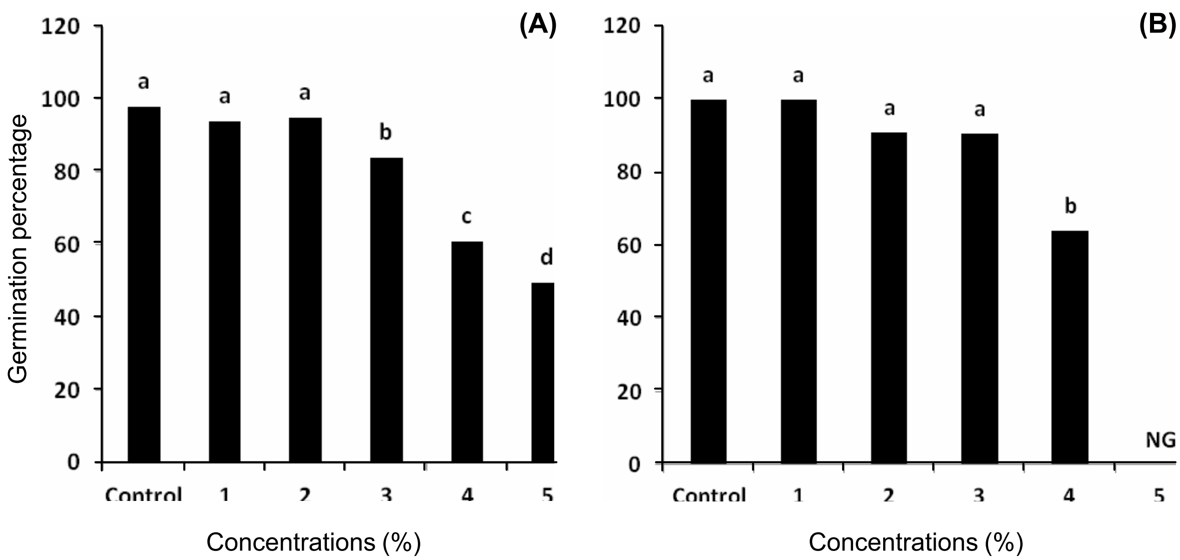
Complete failure of seed germination of rice was recorded as a result of applying aqueous extract from leaf of *A. philoxeroides*. Rice seed germination was about 50% with aqueous leaf extract of *A. sessilis* (Table 2).

Keeping in view the more phytotoxic effects of *A. philoxeroides* and *A. sessilis* leaves on seed germination, studies were extended to monitor the effect of different concentrations of aqueous leaf extract. It was observed that germination of rice seed was measured to be significantly less at 4 and 5% aqueous leaf extract concentration of *A. philoxeroides* and 3, 4 and 5% aqueous concentrations of *A. sessilis* leaves (Figure 2). The inhibition of seed germination was found to be strong with *A. philoxeroides* aqueous extract at higher concentrations as compared to that of *A. sessilis*. Allelopathic effect depends on the concentration levels of

Table 2 - Germination and seedling vigor traits of rice as influenced by leaf aqueous extracts of *A. sessilis and A. philoxeroides* with varied concentrations

Concentration	*A sessilis*						*A philoxeroides*					
	T50	MGT	GI	Root length	Shoot length	SVI	T50 (days)	MET (days)	GI	Root length	Shoot length	SVI
(%)	(days)			(cm)			(days)			(cm)		
Control	1.98 d	2.64 d	9.73 a	3.35 a	5.42 a	328.0 a	1.61 e	2.25 e	11.60 a	3.56 b	6.67 b	355.8 b
1	3.32 c	3.85 c	6.23 c	3.26 a	5.23 a	305.9 ab	2.73 d	3.21 d	8.61 b	4.39 a	7.10 a	439.0 a
2	2.86 c	3.46 c	7.36 b	2.92 b	4.42 b	277.7 b	3.56 c	4.32 c	6.30 c	3.19 b	5.42 c	290.7 c
3	4.44 b	5.48 b	4.34 d	2.80 b	3.93 c	234.7 c	4.69 b	4.81 b	5.33 d	3.16 b	5.42 c	285.6 c
4	5.86 a	6.31 a	2.59 e	1.93 c	3.78 c	117.3 d	7.28 a	8.15 a	2.27 e	1.78 c	3.15 d	115.2 d
5	5.26 a	5.74 b	2.67 e	1.29 d	2.20 d	63.8 e	NG	NG	NG	NG	NG	NG
LSD	0.634	0.489	1.044	0.214	0.327	32.03	0.325	0.414	0.656	0.412	0.328	53.00

Means sharing the same letters in a column do not differ significantly at 0.05 probability. Level according to Least Significance Difference test (LSD).



Bars of treatments having letters in common do not differ significantly at the 5% probability level according to the Least Significance Difference test (LSD). NG = Not germinated.

Figure 2 - Germination percentage of rice as influenced by aqueous leaf extracts of various concentrations of (A) *A. sessilis and* (B) *A. philoxeroides*.

the extracts and the parts of the weed from which they were extracted. The inhibitory allelopathic effect of the leaf extract of both *Alternanthera* species was stronger than that of other plant parts. It indicates that leaves produce water soluble phytotoxins in a concentration which can inhibit germination to a greater extent. The leaching of toxins by soaking different plant parts of *Alternanthera* species in water suggested a possible mechanism of toxin transport that would function in nature. These results are supported by Dongre and Yadav (2005) and Tanveer et al., (2008 and 2010), who stated that some parts of weeds have a more marked inhibitory effect than others. A phytochemical analysis had already reported high accumulation of growth inhibitors in leaves of *Alternanthera* species than in other plant parts (Table 5).

Rice emergence percentage was greatly reduced by whole plant residues of *A. philoxeroides* and *A. sessilis* incorporated in the soil at 1, 2, 3 and 4% compared to soil alone (control) as evident from Figure 3. *Alternanthera philoxeroides* reduced rice emergence rate by 51.0, 0, 78.0, 97.0 and 100.0% at 1, 2, 3 and 4%, respectively in comparison with control. The respective values with *A. sessilis* were 23.0, 53.0, 79.0, and 80%. Our study indicates that *Alternanthera* species residues have inhibitory effects on emergence of rice seedlings and an increase in phytotoxicity was observed with increased concentration of residues. It could be related to their more concentration, release of more allelochemicals and availability in soil. These results are supported by the findings of Tanveer et al. (2010). They recorded significant reduction in emergence of wheat, chick pea and lentil in *Euphorbia helioscopia* infested soil.

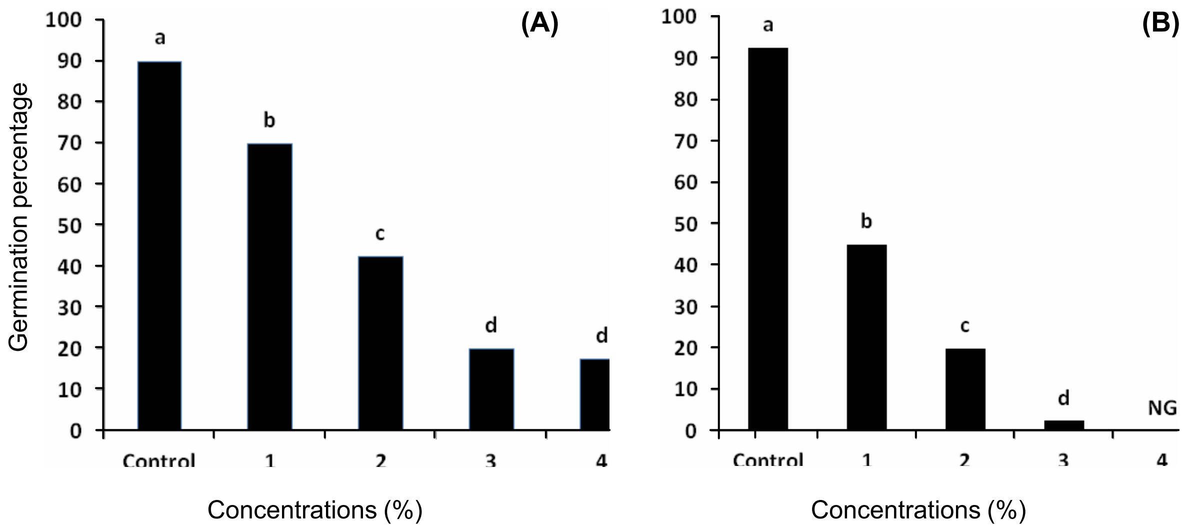
Data presented in Table 3 reveal that *A. sessilis* residues at 1% increased time to 50% emergence, mean emergence time and germination index as compared to other concentrations. Decrease in these seed emergence traits was due to fewer emergences of seeds with increased concentrations of *A. sessilis* residues. *Alternanthera sessilis* residues exerted a significant inhibitory effect on seedling root, shoot length and their dry weight at all concentrations except 1%, which stimulated seedling growth. Delay in time to 50% emergence of rice and mean emergence time of rice seeds with *A. philoxeroides* residues was more pronounced at 1 and 2% concentrations as compared to 3%. *Alternanthera philoxeroides* residues had stimulatory effect on seedling growth of rice at 1% but above this concentration, the effect was inhibitory.

These results indicate that *Alternanthera* residues release growth retardatory substances into the soil, which accumulate in bioactive concentrations and adversely affect the growth of rice seedlings. More delay in seed emergence and reduction in seedling growth of rice with *A. philoxeroides* residues compared with those of *A. sessilis* could be attributed to a more marked inhibitory effect of allelochemicals present in the former weed (Table 4). Increase in seedling growth of rice

Table 3 **-** Emergence and seedling vigor trait of rice as influenced by *A. sessilis* residue amended soil

Residue content (%)	T_{50} (days)	MET (days)	GI (days)	Root length (cm)	Shoot length (cm)	Root dry weight (mg seedling^{-1})	Shoot dry weight (mg seedling^{-1})	SVI
Control	4.26 c	4.32 c	4.03 a	3.21 b	8.59 a	7.35 b	19.33 a	289.49 a
1	7.75 a	7.83 a	1.33 b	4.05 a	8.88 a	8.93 a	19.60 a	279.96 a
2	6.40 b	6.47 b	0.52 c	2.74 b	7.13 b	5.74 c	14.82 b	115.67 b
3	3.80 cd	4.05 c	0.23 c	1.64 c	6.00 c	3.46 d	12.57 c	32.75 c
4	3.05 d	3.29 d	0.19 c	1.06 c	4.52 d	2.24 e	9.14 d	18.21 c
LSD	0.985	0.632	0.360	0.632	0.582	0.993	1.782	31.613

Means sharing the same letters in a column do not differ significantly at 0.05 probability. Level according to Least Significance Difference test (LSD).



Bars of treatments having letters in common do not differ significantly at the 5% probability level according to the Least Significance Difference test (LSD). NG = Not germinated.

Figure 3 - Emergence percentage of rice as influenced by residue amended soil of (A) *A. sessilis* and (B) *A. philoxeroides* with varied concentrations.

Table 4 - Emergence and seedling vigor traits of rice as influenced by *A. philoxeroides* residue amended soil

Concentration	T_{50}	MET	GI	Root length	Shoot length	Root dry weight	Shoot dry weight	SVI
(%)	(days)			(cm)		(mg seedling^{-1})		
Control	3.36 b	3.89 b	2.46 a	3.07 b	10.24 a	7.09 b	23.55 a	283.3 a
1	12.95 a	13.08 a	0.43 b	4.56 a	11.26 a	10.40 a	24.77 a	208.9 a
2	13.06 a	13.79 a	0.12 bc	1.03 c	3.38 b	2.18 c	7.10 b	21.8 b
3	2.88 b	2.99 b	0.03 c	0.60 c	1.40 b	1.27 c	2.97 c	1.4 b
4	NG	NG	NG	NG	NG	NG	NG	NG
LSD	1.046	1.306	0.358	1.044	4.658	1.427	2.108	91.195

Means sharing the same letters in a column do not differ significantly at 0.05 probability. Level according to Least Significance Difference test (LSD).

Table 5 - Phytotoxic composition of aqueous leaf extracts

Sr. No.	Phenolics	Concentration (mg L^{-1})	
		A. sessilis	*A. philoxeroides*
1	gallic acid	11.03	-
3	4-hydroxy-3-methoxy benzoic acid		16.19
4	p-coumeric acid		1.48
5	m-coumeric acid	-	2.103
6	vanillic acid	9.88	
7	ferulic acid	10.25	-
8	cholorogenic acid	17.85	
		49.01	19.773

Table 6 - Total amount (ug g^{-1}) of water soluble phenolics in extracts of *Alternanthera* species

Plant part	*Alternanthera sessilis*	*Alternanthera philoxeroides*
Whole plant	44	75
Flower	52	-
Leaves	100	93
Stem	50	65
Root	60	58

at 1% residue concentration of *A. sessilis* and *A. philoxeroides* could be attributed to the presence of allelochemicals which had stimulatory effect (Kadioglue et al., 2005).

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