Rajan Katoch, Anita Singh, Neelam Thakur/ International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 5, September- October 2012, pp.828-834

Effect Of Weed Residues On The Physiology Of Common Cereal Crops

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Abstract

The allelopathic influence of plant residues of three dominant weeds of North-Western Himalayan region, namely, *Eupatorium adenophorum, Ageratum conyzoides* and *Lantana camara* was observed on the germination and early growth of three common cereal crops *viz.*, *Triticum aestivum* cv. HPW-42, *Oryza sativa* cv. Hasanshrai Basmati and *Zea mays* cv. Girija. The effect of soil amended with weed residues at two concentrations (5 g/100 g soil and 10 g/100 g soil) was compared with control. Among the test crops, maize with larger seeds was least sensitive to the exposure to various treatments while wheat and paddy with small seeds were comparatively susceptible. The incorporation of weed residue in soil had inhibitory effect on the per cent germination and shoot length of seedlings of test crops. The results of the study indicated the allelopathic influence of weed residue on the physiology of the crop plants. Therefore, the intensive studies on allelochemicals released from decaying weed residues in the natural environment where additive or synergistic effects become significant even at low concentrations are desirable to provide detail information on the influence of the weeds on crops of economic interest.
Abbreviations:

Key words: weeds, weed residue, germination, shoot length, *Triticum aestivum*, *Oryza sativa*, *Zea mays*

Introduction

Weed infestation is one of the major causes of yield reduction in crops. The incidence of allelopathic effect of weeds on growth of crops has become increasingly widespread. When the two plant species grow together, they interact with each other either inhibiting or stimulating their growth or yield through direct or indirect allelopathic interaction (Kumar et al. 2006). Several reports have documented the deleterious effect of decaying weed residues on the growth and yield of subsequent crops in the field (Guenzi and McCalla 1966, Shaukat et al. 1985, 2003, Burhan and Shaukat 1999, Singh et al. 1988, Angiras et al. 1987, 1988, Das and Choudhury 1996). The effects of decaying weed residues depend upon the release of allelochemicals from them into the soil. These chemicals may be washed directly from the residues, or may result from microbial activity during decomposition (Putnum and Duke 1978, Lynch and Cannell 1980, Kumar et al. 2006). The effect of allelopathic chemicals tends to be highly species-specific (Stowe 1979, Melkania 1983). Normally, the effect is harmful, but beneficial effect is also possible (Newman 1978).

Ageratum conyzoides, Lantana camara and Eupatorium adenophorum are three exotic rapidly spreading weed species which have successfully invaded a large portion of North-Western Himalayan region in India. They are a major problem for the environmentalists, ecologists and agriculturists. The present investigation was carried out to assess the allelopathic potential of the plant residues of these common weeds of North-Western Himalayan region on the important cereal crops *viz.*, *Triticum aestivum* cv. HPW-42, *Oryza sativa* cv. Hasanshrai Basmati and *Zea mays* cv. Girija.

Materials and Methods

Collection and mechanical processing of plant material

Fresh plant material (whole plant) of *E. adenophorum*, *A. conyzoides* and *L. camara* was collected from the vicinity of CSKHPKV, Palampur, India. The collected plant samples were allowed to shade dry. The dried material was crushed into fine powder using grinder and sieved through mesh of 2mm pore size.

Procurement of seeds

Seeds of the cereal crops studied were procured from the Department of Crop Improvement, CSKHPKV, Palampur. The seeds were surface-sterilized with sodium hypochlorite and used for further bioassay studies.

Pot experiment

To study the effect of decaying weed residue on germination and seedling growth of test crops, dried powdered material of *E. adenophorum*, *A. conyzoides* and *L. camara* was mixed thoroughly with Soilrite™ consisting of peat moss, perlite and vermiculite (1:1:1 v/v/v) at the concentration of 5 g/100 g soil and 10 g/100 g of soil. After mixing, the soil was equally transferred into plastic pots of 9.5 cm diameter. Pots were watered once and soil was left for biodegradation. The pots were kept in a glasshouse under controlled conditions. After one week, 10 seeds of test crops were sown in each pot. For controls, Soilrite™ with no weed residue was used. The experiment was carried out in triplicate for each treatment and control. Seedlings were irrigated with tap water throughout the experiment. Pot experiment included the following treatments:

T_0: Soilrite™
T_{E5}: Soilrite™ + *E. adenophorum* (5 g/100 g soil)
T_{E10}: Soilrite™ + *E. adenophorum* (10 g/100 g soil)
T_{A5}: Soilrite™ + *A. conyzoides* (5 g/100 g soil)
T_{A10}: Soilrite™ + *A. conyzoides* (10 g/100 g soil)
T_{L5}: Soilrite™ + *L. camara* (5 g/100 g soil)
T_{L10}: Soilrite™ + *L. camara* (10 g/100 g soil)

The experiment was extended over a period of fourteen days to allow maximum seedling growth. The seed was considered germinated when the plumule emerged. Germination counts were made daily up to seven days. The length of shoot of seedlings was recorded initially on seventh day and then on fourteenth day after sowing. On fourteenth day post-sowing, the weight of shoot and root of various treatments of all the test crops was recorded.

Statistical Analysis

Three replications were maintained and completely randomized design was followed for statistical analysis (Panse and Sukhatme 1989). The data were subjected to analysis of variance (ANOVA) at $p \leq 0.05$. In case of values found non-significant during ANOVA, the data was subjected to Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$.

Results

Effect of weed residues on seed germination

The germination per cent of seeds of all the test crops under the influence of various treatments is presented in Table 1. The per cent germination of wheat seeds in soil amended with *E. adenophorum* (5 g/100g soil) was significantly higher as compared to the control while all other treatments showed significantly lower per cent germination. No significant reduction in the per cent germination of seeds of paddy was observed in the soil amended with 5 g/100 g soil of either *E. adenophorum* or *A. conyzoides* or *L. camara* as compared to the control. However, significant reduction in per cent germination of paddy seeds was observed when the soil was amended with 10 g/100 g soil of either *E. adenophorum* or *A. conyzoides* or *L. camara* as compared to the control or corresponding treatment at 5 g/100 g soil. Maximum inhibition was revealed by *L. camara* amended soil (10 g/100 g soil). In case of maize, the per cent germination was not significantly altered by various treatments except *E. adenophorum* (10 g/100 g soil) which showed significant inhibition as compared to the control.

Effect of weed residues on shoot weight

The shoot weight (g) of seedlings of all test crops under the influence of various treatments on fourteenth day after sowing is presented in Table 1. The shoot weight of wheat seedlings grown in soil amended with *E. adenophorum* (5 g/100 g soil) and *L. camara* (5 g/100 g soil and 10 g/100 g soil) was significantly higher as compared to the control. Wheat seedlings of all other treatments showed significantly lesser shoot weight as compared to the control. No significant change in shoot weight of paddy seedlings was observed in all the treatments as compared to the control. However, *A. conyzoides* (5 g/100 g soil) led to significantly higher shoot weight of paddy seedlings as compared to other treatments. The shoot weight of maize seedlings exposed to various treatments was significantly higher than the control.

Effect of weed residues on root weight

The root weight (g) of seedlings of all test crops under the influence of various treatments on fourteenth day after sowing is presented in Table 1. The root weight of wheat seedlings grown in soil incorporated with *E. adenophorum* (5 g/100 g soil and 10 g/100 g soil), *A. conyzoides* (5 g/100 g soil) and *L. camara* (5 g/100 g soil) was significantly higher as compared to the control. No significant difference was observed in the root weight of wheat seedlings grown in soil incorporated with *A. conyzoides* (10 g/100 g soil) and *L. camara* (10 g/100 g soil) as compared to the control. The root weight of paddy seedlings grown in soil incorporated with *E. adenophorum* (10 g/100 g soil) was statistically similar to the control while all other treatments revealed significantly higher root weight on fourteenth day post-sowing. The root weight of maize seedlings grown in soil incorporated with *E. adenophorum* (5 g/100 g soil and 10 g/100 g soil) was statistically similar to the control while all other treatments revealed significantly higher root weight on fourteenth day post-sowing.

Effect of weed residues on shoot length

On seventh day, a significant reduction in the shoot length of wheat, paddy and maize was observed for all the treatments except paddy grown in soil amended with *A. conyzoides* (5 g/100 g soil). On fourteenth day, the shoot length of wheat seedlings was significantly less in the soil amended with *E. adenophorum* (10 g/100 g soil) and *A. conyzoides* (5 g/100 g soil and 10 g/100 g soil) as compared to the control. All other treatments showed statistically similar shoot length of wheat seedlings. The paddy seedlings grown in different amended soil showed significantly lesser shoot length as compared to the control. In case of maize, significantly lesser shoot length was observed in soil amended with *E. adenophorum* (10 g/100 g soil) and *A. conyzoides* (10 g/100 g soil) as compared to the control.

Discussion

The present investigation clearly presented the allelopathic influence of decaying weed residue of *E. adenophorum*, *A. conyzoides* and *L. camara* on the germination and seedling growth of cereal crops *viz.*, wheat, paddy and maize. This could be assigned due to release of allelochemicals or toxins into the soil from the decaying residue by the action of micro-organisms during decomposition (McCalla and Duley 1948, Cochran et al. 1977, Putnum and Duke 1978, Lynch and Cannell 1980, Harper and Lynch 1982, Lovett and Jessop 1982, Kumar et al. 2006). The potential effect is dependent on numerous factors that together govern the rate of residue decomposition, the net rate of active allelochemical production and the subsequent degrees of phytotoxicity (An et al. 2002). The effects of secondary substances released by these mechanisms can be long lasting (Patrick 1971) or quite transitory (Kimber 1973) and can ultimately influence practices like fertility, seeding and crop rotations. An (2005) discussed about a model which provides an integrated view of the allelopathic pattern of plant residues during decomposition, in terms of both the response of a receiver plant and allelochemical dynamics in the environment. They proposed two aspects of allelopathy, stimulation and inhibition. The extent of each over the whole course of residue decomposition is not balanced. They reported that the most severe inhibition occurs at the early stages of residue decomposition. Phytotoxicity was reported to proceeds from stimulation to inhibition and reach its maximum of inhibition soon after decomposition starts.

In the present studies, soil incorporation of the weeds under investigation was found to have inhibitory effect on the per cent germination and shoot length while a stimulatory effect was observed for shoot weight and root weight of seedlings. Earlier studies have also revealed that situations abound where allelochemicals inhibit seed germination, but seedling growth, and perhaps other growth parameters, remain unaffected. Wilson and Rice (1968) have reported both stimulatory and inhibitory effects on various crop species with decaying materials.

The allelopathic inhibitory effect of decaying weed residue of *E. adenophorum*, *A. conyzoides* and *L. camara* was found to be more pronounced during the seed germination and early days of seedling growth. The allelochemicals released from decaying weed residue into the soil may remain active and stable to affect the germination and early growth of the successive crop by interfering with the plant growth processes or by reducing cell division or auxin induced growth of roots (Patrick and Koch 1958, McCalla and Haskins 1964). The allelochemical can directly affect the growth of receiver plants in soil as they are directly available for absorption by the plant (Kobayashi 2003). The allelochemicals absorbed by the seedling may slowly get metabolized. Earlier workers have also reported inhibition of seed germination by allelochemicals through their interference in energy metabolism, cell division, mineral uptake, blockage of hydrolysis of nutrients reserve and biosynthetic processes (Rice 1984, Irshad and Cheema 2004) and these factors may cause significant reductions in the growth of plumule and radical of various crops (Ogbe et al. 1994).

The stimulatory effect for shoot weight and root weight may emerge either from growth promoting compounds in the tissues themselves or enhanced microbial activity and concomitant nutrient availability (Rice 1986). As the allelopathic effects are both stimulatory and inhibitory, both of these effects can be utilized for higher crop production (Oudhia et al. 1999a). Stimulatory allelopathic effects of any weed on crops can be utilized to develop ecofriendly, cheap and effective ‘green growth promoters’ while inhibitory allelopathic effects of any weed or crop on weeds can be utilized to develop ‘green herbicides’ (Oudhia et al. 1999b).

Among the test cereal crops, maize with larger seeds was less sensitive to the decaying weed residue while wheat and paddy with small seeds was more susceptible to the allelopathic effect of decaying weed residue during germination. This observation is in agreement with the findings of Lucena and Doll (1976) who observed that seed size is an important factor and species with small seeds are more adversely affected. Moreover, the inhibition of seed germination and seedling growth was concentration-dependent and numerically more inhibition was observed at higher concentrations. These results correlated with the earlier reports indicating that allelopathy is a concentration-dependent phenomenon and includes both stimulatory and inhibitory activities (Wilson and Rice 1968, Rai and Triputhi 1984, Rizvi and Rizvi 1987).

Most of the earlier studies had revealed that the inhibition obtained in the laboratory experiments might differ from the situations in the fields as allelopathic effects are often due to synergistic activity of allelochemicals rather than to single compound. (Hauser 1993, Lisanework and Michelsen 1993, Tian and Kang 1994, Mehar et al. 1995, Hansen-Quartey et al.1998). Under field conditions, additive or synergistic effects become significant even at low concentrations (Einhelliing and Rasmussen 1978). Thus, intensive studies on allelochemicals from decaying weed residues are still desirable to provide detail information on their effects as farmers often leave weed residues uncared for in their fields.

Different groups of workers have reported that *E. adenophorum* contains a large amount of allelochemicals especially in the leaves, which inhibit the growth of many plants in nurseries and plantations (Ambika and Jayachandra 1980, Eze and Gill 1992, Gill et al. 1993, Zhao et al. 2009). Similarly, allelochemicals from *A. conyzoides* have been reported to inhibit seed germination and seedling growth of many plants (Wei et al. 1997, Batish et al. 2006). Significant amount of water-soluble phenolics are reported to be present in *A. conyzoides* infested soil, leaf debris, and debris-amended soils (Batish et al. 2009). Our study is in agreement with earlier studies where leaf debris of *A. conyzoides* have been reported to deleteriously affect the early growth of rice (Batish et al. 2009) and wheat (Singh et al. 2003) by releasing water-soluble phenolic acids into the soil environment. Xuan and coworkers (2004) have also reported allelopathic effect of *A. conyzoides* leaves on paddy weeds. Allelopathic effects of *Lantana camara* on germination and seedling vigour or many agricultural crops have been reported (Oudhia et al. 1998, Oudhia and Tripathi 1999).

Conclusion

The allelopathic activity of decaying weeds residue is due to the various phytotoxic compounds released during their decomposition into the soil which may independently or jointly contribute to plant growth regulatory effect and inhibit germination. The present study provides the evidence of allelopathic potential of *E. adenophorum*, *A. conyzoides* and *L. camara* on three cereal crops, namely, wheat, paddy and maize. However, more detailed investigation is needed to study the specific role in different crops. These results suggest major inhibitory effect of decaying weeds residue during germination and early seedling growth of test crops while a stimulatory effect on shoot weight and root weight of seedlings of test crops. Further investigation is needed to identify the active compound(s) of the extracts responsible for their activity. The effect of these weeds on the germination and seedling growth of these crops in the natural environment where additive or synergistic effects become significant even at low concentrations should also be investigated.

Acknowledgements

The financial assistance provided by the Department of Biotechnology, New Delhi, Government of India, for funding the research project is duly acknowledged.

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Table 1: Effect of decaying residue of *E. adenophorum*, *A. conyzoides* and *L. camara* in soil on the germination per cent of test crops (on seventh day post-sowing) and weight of shoot and root of test crops (on fourteenth day post-sowing)

S.No.	Treatment	Germination (%)			Shoot weight (g)			Root weight (g)		
		Wheat	**Paddy**	**Maize***	**Wheat**	**Paddy**	**Maize***	**Wheat**	**Paddy**	**Maize**
1.	T_{0M}	73.30^{b}	96.7^{a}	96.7	0.101^{b}	0.036^{ab}	0.95	0.011^{de}	0.021^{d}	0.356^{d}
2.	T_{1E5}	100.00^{a}	96.7^{a}	96.7	0.143^{a}	0.030^{b}	1.07	0.046^{a}	0.027^{bc}	0.406^{d}
3.	T_{1E10}	36.70^{d}	43.3^{c}	70.0	0.047^{c}	0.027^{b}	1.31	0.028^{bc}	0.023^{d}	0.384^{d}
4.	T_{2A5}	13.30^{e}	86.7^{a}	83.3	0.052^{c}	0.045^{a}	1.19	0.027^{bc}	0.029^{ab}	0.537^{c}
5.	T_{2A10}	00.0^{e}	60.0^{b}	83.3	0.00^{d}	0.033^{b}	1.16	0.000^{e}	0.027^{bc}	0.518^{c}
6.	T_{3L5}	53.3^{c}	86.7^{a}	83.3	0.139^{a}	0.032^{b}	1.36	0.034^{b}	0.026^{c}	0.588^{b}
7.	T_{3L10}	46.7^{cd}	26.7^{d}	80.0	0.136^{a}	0.028^{b}	1.15	0.022^{cd}	0.030^{a}	0.762^{a}
GM		46.19	70.97	84.76	0.088	0.033	1.17	0.024	0.026	0.507
F value		52.40	40.78	2.42	31.84	4.201	1.72	20.73	18.37	76.01
S.E.		6.67	6.17	-	0.014	0.004	-	0.005	0.001	0.023
C.D. (5%)		14.31	13.23	-	0.030	0.009	-	0.011	0.002	0.049

Data were subjected to analysis of variance (ANOVA)/ *Duncan's multiple range test (DMRT)
Values with different superscripts in each column are significantly different at $p \leq 0.05$. Non-significant data are represented by N.S.

Table 2: Effect of decaying residue of *E. adenophorum*, *A. conyzoides* and *L. camara* in soil on the shoot length of test crops on seventh and fourteenth days after sowing

S.No.	Treatment	Shoot length (cm)					
		On seventh day			On fourteenth day		
		Wheat	Paddy	Maize	Wheat	Paddy	Maize
1.	T_{0M}	20.4^{a}	5.63^{a}	19.4^{a}	22.9^{a}	21.4^{a}	37.1^{ab}
2.	T_{1E5}	13.4^{c}	2.63^{c}	11.8^{bc}	22.6^{a}	16.1^{c}	37.0^{ab}
3.	T_{1E10}	2.57^{d}	2.40^{c}	10.2^{bc}	7.00^{b}	13.4^{d}	29.9^{c}
4.	T_{2A5}	4.07^{d}	4.20^{ab}	9.83^{c}	6.97^{b}	19.0^{b}	38.1^{ab}
5.	T_{2A10}	0.00^{e}	2.97^{bc}	12.3^{bc}	0.00^{c}	13.7^{d}	34.5^{bc}
6.	T_{3L5}	16.8^{b}	2.33^{c}	13.6^{b}	23.4^{a}	16.0^{c}	39.5^{a}
7.	T_{3L10}	15.4^{b}	3.13^{bc}	9.40^{c}	21.9^{a}	16.2^{c}	37.3^{ab}
GM		10.38	3.33	12.36	14.97	16.54	36.2
F value		162.2	5.481	8.179	318.3	25.46	4.869
S.E.		0.89	0.72	1.70	0.79	0.79	2.03
C.D. (5%)		1.91	1.54	3.65	1.69	1.69	4.35

Data were subjected to analysis of variance (ANOVA) and values with different superscripts in each column are significantly different at $p \leq 0.05$.