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Allelopathic effects of root exudates of purple nutsedge (*Cyperus rotundus* L.) on growth of field crops

M. AMEENA, V. L. GEETHAKUMARI AND S. GEORGE

Department of Agronomy
College of Agriculture, Kerala Agricultural University
Thiruvananthapuram-695522, Kerala

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ABSTRACT

Purple nutsedge, (Cyperus rotundus L.), a native of India is a pernicious perennial weed in many crops in more than 90 tropical and subtropical countries and is ranked as one of world's worst weeds. It asserts allelopathic effects on crop plants through inhibition of germination, growth or metabolism. Under field conditions, the deleterious effect of weeds may be facilitated by exudates, leachates from decomposing residues and residues incorporated to the growing medium. In the present study, laboratory experiments were carried out to investigate the allelopathic influence of nutsedge root exudates collected at different growth stages of the weed viz. sprouting, tuberisation, flowering and dormant tuber formation on seedling growth of rice, cowpea, sesamum, okra and brinjal. Exudates were collected at different growth stages of the weed and their effect on germination percentage, radicle length, plumule length and dry matter production and the vigour index (VI) of important field crops were observed to assess the effect of exudates. The nutsedge root exudates collected at sprouting stage inhibited the germination and growth of all the crop seeds tested which would be due to the release of some inhibitory chemicals from nutsedge tubers into the medium during the process of sprouting. However, the exudates collected at later stages did not elicit any response on growth characters of crop seeds. Significant reduction in vigour index was observed in sesamum and okra indicating that nutsedge inhibits the growth of associated crops by the production of inhibitory substances as root exudates. However, such an inhibitory effect on the development of plumule and radicle was not observed in rice, cowpea and brinjal. The tuber extracts of nutsedge as identified by HPLC technique revealed the presence of phenolic compounds viz.p-hydroxy benzoic acid, gentisic acid, caffeic acid, o-coumaric acid and ferulic acid. The results from our study suggest that compounds from Cyperusrotundus especially after flowering can serve as lead molecules for the synthesis of bioherbicides.

Keywords: Allelochemicals, allelopathy, purple nutsedge, root exudates, vigour index.

Nutsedge asserts allelopathic effects on crop plants through inhibition of germination, growth or metabolism. Under field conditions, the deleterious effect may be facilitated by exudates, leachates from decomposing residues and residues incorporated to the growing medium (Garcia and Anderson, 1984). Exudation of chemicals by the plant is a common phenomenon. Root exudates are substances released into the surrounding medium by healthy and intact plant roots. The term 'root exudates' is used in a broad sense to refer to organic substances which are exuded from the roots by any mechanism (Rovira, 1969). Under normal growth conditions, exudation probably represents a major mechanism of releasing organic chemicals into the rhizosphere. The chemistry of the bioactive compounds in the rhizosphere is of fundamental importance to the understanding of interactions between the plant root systems and other living organisms. Though the information on the allelopathic effects of many weed species is available, relatively less information is available regarding the effect of purple nutsedge root exudates on the growth of crop plants. Therefore, the present investigation was undertaken to study the effect of nutsedge root exudates on seedling growth of four important groups of crops which would determine the yield.

Email: drameenaubaid@gmail.com

MATERIALS AND METHODS

The study was conducted on rice, cowpea, sesamum, okra and brinjal to represent the major four groups of crops *viz*., cereals, pulses, oilseeds and vegetables. Exudates were collected at different growth stages of the weed during summer season by fabricating a device as designed by Tang and Young (1982) and their effect on germination percentage, radicle length, plumule length and dry matter production were observed and the vigour index (VI) was computed to assess the effect of exudates. The experiment consisted of 5 treatments with T_1 – Roots exudates collected at sprouting stage, T_2 – Root exudates collected at tuberisation stage, T_3 - Root exudates collected at flowering stage, T_4 - Root exudates collected at dormant tuber formation stage and T_5 – Control (distilled water). The experiment was laid out in Completely Randomised Design with 4 replications. The system for collection of root exudates consisted of a stainless steel vessel which was connected to a glass tube with the help of a rubber stopper. The glass tube was filled with one per cent (100: 1) sand charcoal mixture. Nutrient solution leached through the soil and adsorbent column was cycled to the soil and column with the help of a rubber tube and air pump. The bottom end of the side arm was inserted into the glass column and the top end was let to stand over the mouth of the container. This system ensured a steady and constant circulation of the flow from the container through the sand-charcoal mixture. The exudates were collected at various growth stages of the weed *viz*., sprouting stage, tuberisation stage, flowering stage and dormant tuber formation stage. The stainless steel vessel was filled with 1.75 kg white sand which is washed thoroughly and sterilized at a temperature of 100°C for two days. Twenty tubers of nutsedge were sown in the container and irrigated. Once the weed reached the growth stage as indicated in treatments 1 to 4, the attachment of glass column was filled with the adsorbent (50 g). The system was then connected to an air pump. After the solution had been recirculated through the system for 72 hours, each loaded column was detached and eluted sequentially five times with 50 ml of methanol each time. The eluate was concentrated at low temperature using a rotary vacuum flash evaporator and the final volume was made upto 25 ml. Glass petri dishes (9 cm diameter) were sterilized at an atmospheric pressure of 15 lb inch^{-2} for one hour and later dried in hot air oven at 120^{0}C. Seeds of test plants were sterilised by dipping in 0.1 per cent $HgCl_2$(Mercuric chloride) solution for five minutes followed by repeated washing with distilled water to remove residues of $HgCl_2$ and dried in folds of ordinary filter paper. In each petri plate a filter paper was kept at bottom and thereafter 2 ml of the exudate was poured on the filter paper so as to impregnate it with the chemical in the exudates. After impregnating the filter paper 50 seeds each of the test crop were arranged in circles on the top of the filter paper. Then 5 ml of distilled water was added on each petri plate. Thereafter 2 ml of distilled water was added uniformly as and when required till the end of the trial. The data on germination and seedling growth were recorded and analysed statistically.

RESULTS AND DISCUSSION

The study revealed that germination percentage was inhibited by the exudates collected at sprouting stage on all the crop seeds tested. This would be due to the release of some inhibitory chemicals from nutsedge tubers into the medium during the process of sprouting. According to Whittakar and Feeny (1971), the known allelopathic agents are secondary plant metabolites including phenolic acids and flavanoids and other aromatics, terpenoids, steroids, alkaloids and organic cyanides. However, the exudates collected at later stages did not elicit any response on growth characters of crop seeds. This may be because of other types of chemical reactions such as oxidation, polymerization and microbial degradation which would occur to less stable compounds (Tang and Young, 1982).Allelochemicals refer mostly to the secondary metabolites produced by the plants and are bye-products of primary metabolic processes. These secondary metabolites play greater role in reduction as well as enhancement of germination, establishment, growth, development and final biomass production of various species (Lal and Oudhia, 1989).Significant reduction in vigour index was observed in sesamum and okra by the exudates collected at all stages. This reduction in vigour index is due to the adverse effect on the growth and development of plumule and radicle which finally resulted in poor biomass accumulation. Such an inhibitory effect on the development of plumule and radicle was not observed in rice, cowpea and brinjal. This differential response may be due to the difference in biochemical composition of the test crops.

Results of the study indicated that purple nutsedge inhibited the growth of the associated crops like okra and sesamum not only by its competitive nature but also due to the production of inhibitory substance as root exudates. This indicates that plants exude sufficient quantities of phytotoxic substance to influence the growth and nutrient uptake of other plants (Young, 1984). There is ample chance of presence of phenolic compounds in trace amounts in the root leachates. Stimulatory effects on germination of cowpea at 5 DAS by nutsedge root exudates is in line with the earlier findings of Ameena (1999) where she reported that nutsedge extract had some stimulatory effects on germination of cowpea and green gram seeds. The study revealed differential toxicity of allelopathic chemicals with exudates at sprouting stage causing inhibition of germination and rest of the treatments having no effect on it. This could be due to variation in the release of allelochemicals through exudation at various growth stages. Similar variation in production of allelochemicals according to the stress experienced by the plant has been reported by Einhellig (1986). Exudates collected at dormant tuber formation stage caused greatest reduction compared to distilled water treatment. These results correspond with the fact that allelochemical production is greatest at dormant tuber formation stage. On the contrary, aqueous extracts prepared from roots of Rauwolfia tetraphylla L. at medium concentrations (50mg ml^{-1}and100mg ml^{-1}) stimulated the seed germination, growth and biochemical constituents (total sugar, protein, aminoacid and DNA and RNA concentrations) of gram (Mandal *et al.,* 2013). For an allelochemical to be used as a herbicide, it should inhibit weeds selectively. Due to the repercussions associated with the use of chemical herbicides, it is desirable to find new plant products that are biodegradable, exhibit structural diversity and complexity and rarely contain halogenated atoms constitute one such class of chemicals (Ashrafi *et al*.,2007). Possibilities include breeding crop plants for increased production of chemicals that inhibit weed growth and producing natural herbicides from phytotoxic chemicals synthesized by plants.In conclusion, plant interference is very complicated in nature, and includes both allelopathy and competition. Separation of allelopathy from competition is a real challenge. It is the first step to be done toward better understanding and justification of allelopathy work.

Table 1: Allelopathic influence of nutsedge root exudates on germination and early growth of rice (*Oryza sativa* L.)

Treatments	Germination percentage		Plumule length(cm)	Radicle length (cm)	Dry weight (mg plant^{-1})	Vigour index
	5 DAS	14 DAS				
T_1	00.00	00.00	00.00	00.00	00.00	00.00
T_2	90.00	98.75	6.55	0.90	2.25	738.25
T_3	90.00	98.75	6.23	0.85	2.70	698.50
T_4	88.75	97.50	6.13	0.93	2.40	670.75
T_5	92.50	100.00	6.75	1.12	2.78	787.50
SEm(±)	**1.57**	**1.17**	**0.18**	**0.09**	**0.15**	**27.70**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS- Non significant, T_1 – Roots exudates collected at sprouting stage ,T_2 – Root exudates collected at tuberisation stage, T_3 - Root exudates collected at flowering stage , T_4 - Root exudates collected at dormant tuber formation stage and T_5 – Control (distilled water).

Table 2: Allelopathic influence of nutsedge root exudates on germination and early growth of cowpea (*Vigna unguiculata*)

Treatments	Germination percentage		Plumule length (cm)	Radicle length (cm)	Dry weight, mg plant^{-1}	Vigour index
	5 DAS	8 DAS				
T_1	00.00	0	00.00	00.00	00.00	00.00
T_2	93.75	100	20.73	14.35	60.38	3507.5
T_3	95.00	100	26.45	16.47	55.51	42.92.50
T_4	97.50	100	23.73	12.50	52.13	3612.50
T_5	91.25	100	26.05	13.60	63.98	3967.50
SEm(±)	**1.25**	**0.00**	**0.99**	**1.54**	**1.77**	**227.88**
LSD (0.05)	**3.55**	**-**	**2.82**	**-**	**5.05**	**-**

Table 3: Allelopathic influence of nutsedge root exudates on germination and early growth of sesamum (*Sesamum indicum*)

Treatments	Germination percentage		Plumule length (cm)	Radicle length (cm)	Dry weight, mg plant^{-1}	Vigour index
	3 DAS	6 DAS				
T_1	00.00	00.00	00.00	00.00	00.00	00.00
T_2	83.75	75.00	4.98	4.10	3.11	862.50
T_3	88.75	97.50	4.00	3.83	3.19	763.25
T_4	87.50	97.50	4.03	3.83	2.72	765.75
T_5	85.00	96.25	5.58	5.63	2.98	1077.75
SEm(±)	**2.04**	**1.33**	**0.16**	**0.19**	**0.12**	**23.87**
LSD (0.05)	**-**	**-**	**0.45**	**0.55**	**-**	**67.85**

Table 4: Allelopathic influence of nutsedge root exudates on germination and early growth of bhindi (*Abelmoschus esculentus* L. Moench)

Treatments	Germination percentage		Plumule length (cm)	Radicle length (cm)	Dry weight, mg plant^{-1}	Vigour index
	4 DAS	21 DAS				
T_1	00.00	00.00	00.00	00.00	00.00	00.00
T_2	78.75	93.75	15.98	4.85	31.61	1952.00
T_3	77.50	93.75	14.98	4.53	27.92	1830.25
T_4	82.50	95.00	14.90	4.45	27.38	1839.00
T_5	81.25	95.00	17.83	5.40	35.19	2207.50
SEm(±)	**2.50**	**2.08**	**0.24**	**0.18**	**1.72**	**47.77**
LSD (0.05)	**NS**	**NS**	**0.68**	**0.50**	**4.89**	**135.81**

Table 5: Allelopathic influence of nutsedge root exudates on germination and early growth of brinjal (*Solanum melongena* L.)

Treatments	Germination percentage		Plumule length(cm)	Radicle length (cm)	Dry weight mg plant^{-1}	Vigour index
	7 DAS	14 DAS				
T_1	00.00	00.00	00.00	00.00	00.00	00.00
T_2	68.75	85.00	6.45	3.95	15.11	887.00
T_3	71.25	85.00	5.83	4.00	12.61	835.00
T_4	70.00	87.50	5.75	3.57	12.48	821.25
T_5	68.75	86.25	6.85	4.33	22.73	949.25
Sem(±)	**2.64**	**2.50**	**0.22**	**0.18**	**0.52**	**43.28**
CD (0.05)	**NS**	**NS**	**0.62**	**NS**	**1.49**	**NS**

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