QUANTIFICATION OF ALLELOPATHIC POTENTIAL OF DIFFERENT CROP RESIDUES FOR THE PURPLE NUTSEDGE SUPPRESSION

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ABSTRACT

Crop residues are well known for their chemical (allelopathic) and physical effects on crops and weeds. Allelopathic potential of different crop residues viz. sorghum, sunflower, brassica (applied alone or in combination) for the purple nutsedge (Cyperus rotundus L.) suppression was investigated in a pot study. Chopped residues were incorporated at 12 t ha^{-1} (6 g kg^{-1} of the soil) into the soil and a weedy check was also maintained. There were six tubers of purple nutsedge in each soil filled pot. Soil incorporation of all the residues substantially delayed the tuber sprouting. Nonetheless combinations of residues showed were more effective in purple nutsedge suppression than sole application of either of them. Sorghum and brassica residues, when applied in combination did not allow any tuber to sprout. There was substantial suppression in final germination by 41-45% from sole application and 27-100% from combination of crop residues. These residues exerted a pronounced negative influence on the shoot and root length by 21-100 and 17-100%, respectively. Likewise, there was 50-100% and 47-100% suppression in shoot and root dry weights, respectively. Hence, this soil incorporation of allelopathic crop residues may be employed in the integrated approach for purple nutsedge management.

Key words: Residues, allelopathic, sorghum, sunflower, brassica, germination, seedling growth, tubers, synergism, sprout, suppression, phytotoxicity.

INTRODUCTION

Purple nutsedge (*Cyperus rotundus* L.) is considered one of the worst weeds of the world; with wide spread distribution in 52 different crops and 92 countries covering tropics as well as sub-tropics on the globe (Rao, 2000). It is very common weed throughout South East

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Asia (Merita and Moody, 1999; Rajput *et al*., 2008). In Pakistan, it is among the most common weeds during summer season in major field crops such as pulses, cotton, sugarcane, direct seeded rice and maize. It may cause 23–89% reduction in yield of associated crops. Reduction in yield of upland rice was as much as 38% in the presence of *Cyperus* (Okafor and DeDatta, 1976). It is highly competitive (Iqbal and Cheema, 2008) and in addition to competition for light, nutrients, and moisture, allelopathic growth inhibition of crop plants has also been reported (Quayyum *et al*., 2000). It can harbor cotton pests, diseases and reduce irrigation efficiency (Rao, 2000).

Tubers are the primary means of propagation and spread of purple nutsedge (Stoller and Sweet, 1987). The longevity of the tubers, the ability to sprout several times (Keeley, 1971), multiple propagation modes and the lack of herbicides that can provide season long control make purple nutsedge difficult to control. Usual weed control methods; manual or mechanical, are laborious, costly, time consuming and weather dependent and kill only the top growth with little effect on tubers. Few selective herbicides for purple nutsedge are available which can provide control only for a short span of time, and are capable of re-sprouting. Moreover, chemical weed control has its own limitations and has resulted in serious ecological and environmental problems over the years as weed resistance, shifts in weed populations that are more closely related to the crops that they infest, minor weeds becoming dominant (Putwain, 1982; Heap, 2007), greater environmental pollution and health hazards (Rao, 2000).

Reducing the dependence upon traditional practices and synthetic herbicides and finding alternative strategies for weed management is the need of time. Allelopathy promises to be one such strategy, which can be put to good use in several ways in agro ecosystems. Allelopathic research can be applied to so many current weed problems in agricultural systems (Putnam *et al*., 1983; Narwal, 1999). Xuan *et al*., (2004) suggested that if crop allelopathy is appropriately exploited for agricultural production, much agronomic importance can be achieved.

Allelopathic potentiality under field conditions can be utilized in different ways i.e. surface mulch (Cheema and Khaliq, 2000), incorporation into the soil (Ahmad *et al*., 1995; Sati *et al*., 2004), aqueous extracts (Iqbal and Cheema, 2007a; Javaid and Anjum, 2006), rotation (Narwal, 2000), smothering (Narwal and Sarmah, 1996; Singh *et al*., 2003) or mix cropping/intercropping (Hatcher and Melander, 2003; Iqbal and Cheema, 2007b).

Crop residues is the name given to plant material left in the field for decomposition after the harvesting/thrashing of a crop is over (Kumar and Goh, 2000). These residues can pose a chemical (allelopathic) as well as a physical effect on the growth and development of subsequent crops and weeds (Lovett and Jessop, 1982; Purvis *et al*., 1985; Mason-Sedun *et al.*, 1986). The main concern regarding the crop residues is their allelopathic effect on the other or same crop plant (Waller, 1987; Thorne *et al*., 1990). The decomposing crop residues release a variety of allelochemicals, particularly the phenolics, in the soil causing adverse effects on the other plants (Nelson, 1996). The exploitation of crop residues as surface mulch can suppress weeds and thus they can be helpful in reducing reliance on herbicides (Worsham, 1991; Weston, 1996).

Phyototoxicity of dried sunflower residues and leaf powder has been reported (Narwal, 1999; Batish *et al*., 2002). Incorporation of sunflower residues in the soil reduced the growth of sorghum, soybean and canary grass. All parts of sorghum plant such as roots, leave and stem as well as germinating seeds release phyto-toxins that can suppress weed growth. Incorporation of (*in situ*) whole sorghum plant or its various parts alone or mixed with each other was found to suppress weed growth in wheat. Cheema *et al*., (2004) stated that sorghum mulch (10-15 t ha^{-1}) decreased the dry weight of purple nutsedge by 38-41%, compared to control. *Brassica campestris* also exhibited inhibitory effect on the weed density in the following year due to decomposition of its residues (due to isothiocynates). Tarahumara Indians in North Mexico use this crop for weed suppression (Chacon and Gliessman, 1982).

Our previous findings suggest that integration of aqueous extracts from these crops controlled grassy weeds better than either single of them (Jamil *et al*., 2009). We hypothesize that the same can be true for the residues of these crops. To the best of our knowledge, up till now no study has considered the possible integration of these residues for suppressing purple nutsedge. A great scope exists for the utilization of these residues in combination with each other. Keeping in view the allelopathic influence of crop/s residues as a natural weed control approach, following pot study was therefore conducted to explore suppression of purple nutsedge by crop residues (sorghum, sunflower, brassica) applied alone or in combination with each other.

MATERIALS AND METHODS

Preparation of plant residues

Field grown mature plants of sorghum, sunflower and Brassica, free of disease and insect attack, were collected from the Agronomic Research Area, University of Agriculture, Faisalabad. Roots were washed with tap water and whole plants were stored at below 5°C until preparation of extract. These plants were washed with distilled water, blotted between two paper towels and then chopped into about

5-cm pieces with a fodder cutter and dried in an oven at 70°C for 48 h. Whole plant residues were mixed into the soil in situ. Treatments comprised of sources of residues (sorghum, sunflower and brassica) and their various combinations incorporated at 6 g residues kg^{-1} soil. Control treatment contained only soil. Four days after incorporation of crop residues, 6 tubers of *C. rotundus* were sown in each pot including the control pots.

Bioassay

Tubers of purple nutsedge collected from Agronomic Research Area, University of Agriculture Faisalabad were cleaned manually to ensure physical purity. These tubers were surface sterilized with water: bleach solution (10:1) for 15 minutes and rinsed with distilled water four times.

Whole plant residues and their various combinations were mixed into the soil in situ at 6 g kg^{-1} soil (12 t ha^{-1}). In combinations, these residues were combined in 1:1. Three days after incorporation, six tubers were sown in each pot (29 x 18cm, 10 kg capacity) filled with air dried, sieved, well mixed soil (with pH of saturated soil paste and electrical conductivity (EC) of the saturation extract of 7.9 and 0.41 dSm^{-1}, respectively). The pots were arranged in completely randomized design with three replicates. The pots were placed in a screen house with natural solar radiations with an average temperature of 35 ± 5°C. These pots were irrigated as and when required to keep the soil moist and avoid water stress.

The experiment was visited daily to record the emergence count according to AOSA (1990) until a constant count was achieved. Time taken to 50% sprouting of tubers (S_{50}) was calculated according to following formulae of Coolbear *et al*., (1984) modified by Farooq *et al*., (2005):

$$S_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{n_j - n_i}$$

where N is the final number of sprouted tubers, and n_i and n_j are the cumulative number of tubers sprouted by adjacent counts at times t_i and t_j where $n_i < N/2 < n_j$.

Mean sprouting (MST) was calculated according to Ellis and Robert (1981) as:

$$MST = \frac{\sum Dn}{\sum n}$$

where n is the number of tubers, which were emerged on day D and D is the number of days counted from the beginning of sprouting. While sprouting Index was calculated as described by AOSA (1983):

$$SI = \frac{\text{No. of sprouted tubers}}{\text{Days of first count}} + ------- + \frac{\text{No. of sprouted tubers}}{\text{Days of final count}}$$

Root and shoot lengths were measured after 28 days. All roots and shoots from each pot were cut separately and oven dried at 70°C for 48 h to get dry biomass of root and shoot; total seedling biomass of seedling was calculated as the sum of biomass of root and shoot. Number of leaves and secondary roots were counted manually and averaged.

Experimental design and statistical analysis

Experiment was conducted using a completely randomized design with three replications. Mean values were separated using least significant differences (LSD) at *P≤0.05* following an analysis of variance technique using the computer statistical program MSTAT-C (Freed and Scott, 1986).

RESULTS AND DISCUSSION

Sprouting traits of purple nutsedge were adversely influenced by the application of crop residues (Table-1). Significant (*P≤0.05*) increase in time to start sprouting and S_{50} over control was provoked by all the treatments. Sole application of residues delayed sprouting by more than 2 days while this duration was more than twice (> 4 days) for their various combinations. Final sprouting percentage was suppressed by 41-45 % by individual application of sorghum, sunflower and brassica residues. Sorghum and sunflower provided same magnitude of suppression and were at par with each other but interestingly their combination gave only 27 % inhibition which was less than that obtained by either single of them. Sorghum and brassica residues when applied in combination did not allow any tuber to sprout. The combination of sunflower and brassica gave 86 % reduction in final sprouting percentage which was at par with that obtained by combining all the three residues (sorghum + sunflower + brassica). Mean sprouting time was also negatively influenced suggesting that sprouting events were not synchronized. Significantly lower sprouting index values as compared to control were noticed for all the treatments.

Shoot and root length of purple nutsedge was significantly (*P≤0.05*) suppressed by the crop residues and their various combinations (Table-2). Sole application of sorghum, sunflower and brassica residues resulted in 21, 40, 29 and 17, 41, 25 % reduction in shoot and root length respectively, while this inhibition value was increased many fold when these residues were combined. Sorghum was not effective in reducing root length over control. The suppressive effects of crop residues were more evident on shoot length of purple nutsedge seedlings.

Leaf score and number of secondary roots also appeared susceptible to the allelopathic effects of the crop residues and were decreased significantly over control. The suppressive influence mediated by combination of crop residues was more pronounced than sole application of individual crop residues of sorghum, sunflower or brassica. A reduction of 53-72 and 47-66 % in shoot and root dry weight of purple nutsedge was forced by sorghum, sunflower or brassica residues. The mixing of residue provided > 90 % suppression in both shoot and root dry weight over control under different possible combinations.

Table-1. Influence of sole and combined application of crop residues on sprouting behaviour of *Cyperus rotundus.*

Treatments	Time to start sprouting (days)	Final sprouting percentage	Time to 50 % sprouting	Mean sprouting time (days)	Sprouting Index
Control	4.33 d*	91.67 a	6.19 bc	7.19 bc	3.48 a
Sorghum residues incorporated at 6 g kg^{-1} soil	5.67 c (30.87)**	54.17 b (-40.91)	5.92 c (-4.42)	6.96 c (-3.25)	1.39 b (-59.87)
Sunflower residues incorporated at 6g kg^{-1} soil	5.67 c (30.87)	54.17 b (-40.91)	6.75 b (9.05)	7.47 bc (3.89)	1.36 b (-60.92)
Brassica residues incorporated at 6 g kg^{-1} soil	6.67 b (53.96)	50.00 b (-45.46)	6.69 b (8.13)	7.74 b (7.60)	1.05 bc (-69.83)
Sorghum + sunflower residues each incorporated at 3 g kg^{-1} soil	6.00 bc (38.57)	66.67 ab (-27.28)	6.83 b (10.39)	7.58 bc (5.38)	1.63 b (-53.26)
Sorghum + brassica residues each incorporated at 3 g kg^{-1} soil	0.00 e (-100.00)	0.00 c (-100.00)	0.00 d (100.00)	0.00 d (-100.00)	0.00 c (-100.00)
Sunflower + brassica residues each incorporated at 3 g kg^{-1} soil	9.00 a (107.85)	12.50 c (-86.36)	8.50 a (37.32)	9.00 a (25.17)	0.18 c (-94.92)
Sorghum + sunflower + brassica residues each incorporated at 2 g kg^{-1} soil [1]	9.00 a (107.85)	12.50 c (-86.36)	8.50 a (37.32)	9.00 a (25.17)	0.11 (-96.84)
$LSD_{0.05}$	**0.94**	**26.86**	**0.71**	**0.65**	**1.09**

*Means with different letters differ significantly at 5% level of probability by LSD test; **Figures given in parenthesis show percent change over control.

Table-2. Influence of sole and combined application of crop residues on early seedling growth of *Cyperus rotundus.*

Treatments	Root			Shoot		
	Length (cm)	Dry weight (g)	Lateral roots	Length (cm)	Dry weight (g)	Leaf score
Control	7.31 a*	0.12 a	4.72 b	25.83 a	0.56 a	6.77 a
Sorghum residues incorporated at 6 g kg^{-1} soil	6.07 ab (-17.01)**	0.04 bc (-63.89)	3.91 b (-17.16)	20.34 b (-21.24)	0.22 b (-60.12)	5.47 bc (-19.25)
Sunflower residues incorporated at 6g kg^{-1} soil	4.31 c (-41.09)	0.04 bc (-66.67)	3.07 bc (-35.03)	15.29 c (-40.81)	0.15 b (-72.62)	4.57 c (-32.55)
Brassica residues incorporated at 6 g kg^{-1} soil	5.44 bc (-25.63)	0.06 ab (-47.22)	7.08 a (50.07)	18.22 b (-29.46)	0.26 b (-52.98)	6.23 ab (-7.93)
Sorghum+sunflower residues each incorporated at 3 g kg^{-1} soil	4.39 c (-39.85)	0.03 bc (-72.22)	3.13 bc (-33.76)	18.18 b (-29.60)	0.28 b (-50.00)	4.89 c (-27.82)
Sorghum+brassica residues each incorporated at 3 g kg^{-1} soil	0.00 e (-100.00)	0.00 c (-100.00)	0.00 d (-100.00)	0.00 e (-100.00)	0.00 c (-100.00)	0.00 d (-100.00)
Sunflower+brassica residues each incorporated at 3 g kg^{-1} soil	2.28 d (-68.86)	0.01 bc (-91.67)	1.00 cd (-78.81)	3.59 d (-86.10)	0.01 c (-98.21)	1.00 d (-85.23)
Sorghum+sunflower +brassica each incorporated at 2 g kg^{-1} soil [1]	2.40 d (-67.17)	0.01 bc (-91.67)	0.67 d (-78.81)	5.20 d (-79.87)	0.01 c (-98.21)	1.00 d (-85.23)
$LSD_{0.05}$	**1.54**	**0.05**	**2.24**	**2.38**	**0.13**	**1.07**

*Means with different letters differ significantly at 5% level of probability by LSD test; **Figures given in parenthesis show percent change over control.

Results suggested that suppressive effects on sprouting traits and seedling growth of purple nutsedge were imposed by the release of phytotoxic allelochemicals from the crop residues in their immediate vicinity. Most of the allelochemicals from residues can be released by leaching or during their decomposition. Allelopathic compounds in crop residues that were incorporated into the soil probably were solubilized rapidly and delayed emergence. These allelochemicals when imbibed by the germinating tubers proved fatal to a number of vital physiological processes thus impairing germination and hampering subsequent seedling growth.

Sprouting traits as time to start sprouting, S_{50}, mean sprouting time, sprouting index and final sprouting percentage were all reflective of the suppressive effects of sorghum, sunflower and brassica residues incorporation. The inhibition of purple nutsedge sprouting and growth may be attributed to the presence of several phytotoxins in sorghum such as gallic acid, protocatechuic acid, syringic acid, vanillic acid, p-hydroxybenzoic acid, p-coumaric acid, benzoic acid, ferulic acid, m-coumaric acid, caffeic acids, p-hydroxybenzaldehyde and sorgoleone (Netzly and Butler, 1986; Cheema *et al*., 2009). Elaborative work of Weston has confirmed the allelopathic potential of sorghum under natural and controlled conditions and has also identified the allelochemicals, their secretions mechanisms and genes regulating them (Weston *et al*., 2002; Weston and Duke, 2003; Weston, 2005). Sunflower also contains several allelochemicals viz. chlorogenic acid, isochlorogenic acid, α-naphthol, scopolin, and annuionones (Macias *et al*., 2002; Anjum and Bajwa, 2005). The members of Brassicaceae family are also reported to exert allelopathic effects on germination and growth of other species (Norsworthy *et al*., 2005) through glucosinolates (Al-Khatib and Boydston, 1999) Residues species varied in their severity against *C*. *rotundus* eliciting sunflower as the more toxic one. The variable influence of sorghum, sunflower and brassica residues on the *C. rotundus* germination and growth may be due to the type and concentration of allelochemicals present in these species (Weston *et al*., 2002; Weston and Duke, 2003; Weston, 2005; Macias *et al*., 2002; Anjum and Bajwa, 2005).

Besides the root inhibition by various crop residues and their combinations, morphological disorders like root twisting and distorting were also observed. This confirms the affect of allelochemicals on root morphology (Jennings and Nelson, 2002).

It appeared that a combination of residues with variety of allelochemicals each having a different mode and site of action was more effective than application of individual crop residues. This increased not only the number of susceptible sites but also the concentration and uptake of allelochemicals. This can also be attributed to synergistic effect of allelochemicals, particularly among phenolics. Even though, if synergism among the allelochemicals did not exist, their additive effect is worthwhile.

CONCLUSION

Present studies conclude that integration of sorghum, sunflower and brassica residues have potential to suppress sprouting and seedling growth of purple nutsedge. These residues can be used as eco-friendly approach for management of this weed provided that maximum levels of phytotoxins entering into the soil encounter the early growth and development of this weed. Field studies, however, need to be conducted to evaluate suppressive efficacy of such residues applied alone and in combination with each other under natural conditions. Moreover, sorghum, sunflower and brassica crop allelopathy may play an important role in different crop rotations managing the spread of purple nutsedge, this aspect also need to be investigated.

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