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Full Length Article

Purple Nutsedge (*Cyperus rotundus*) Control through Interference by Summer Crops

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Abstract

This study evaluated the suppressive effect of several important summer crops on purple nutsedge (*Cyperus rotundus* L.) growth and reproduction for two growing seasons under greenhouse conditions. Mungbean [*Vigna radiate* (L.) Wilczek], cotton (*Gossypium hirsutum* L.), millet [*Pennisetum glaucum* (L.) R. Br.], sesame (*Sesamum indicum* L.), sorghum [*Sorghum bicolor* (L.) Moench], cowpea (*Vigna unguiculata* (L.) Walp.) and groundnut (*Arachis hypogaea* L.) were grown in monocultures and with ten sprouted *C. rotundus* tubers transplanted at 14 days after sowing of crop. At 75 days, different crops in the study reduced the growth of *C. rotundus* by 1–88%. However, the weight per tuber increased in the crop-weed mixture treatments relative to *C. rotundus* grown alone. Sesame was the most effective crop in suppressing *C. rotundus* in terms of different growth parameters (25–88%), followed by cowpea (14–85%) and millet (26–74%). Cotton and groundnut were found least suppressive to *C. rotundus*. Reduction in crop growth due to *C. rotundus* interference ranged from 2–46% and was more pronounced in root growth (4–46%) than the other crop growth and yield parameters. The adverse effect of *C. rotundus* was greater for millet, green gram and cowpea than for cotton and sesame. Our findings suggest that sesame can effectively suppress *C. rotundus*, and different cultivars of sesame may be evaluated under field conditions for their weed suppressing ability. © 2019 Friends Science Publishers

Keywords: Competition; Allelopathy; Weed control; *Cyperus rotundus* L.; Summer crops

Introduction

Weeds are considered a major constraint in most cropping systems (Vissoh *et al.*, 2004) and their effective management in crop production systems is essential for the short- and long-term productivity and profitability of these systems. Purple nutsedge (*Cyperus rotundus* L.) is considered one of the most problematic weeds in the world due to its perennial nature, longevity and viability of tubers, and abundant tuber production (Horowitz, 1972; Bangarwa *et al.*, 2012). It is a highly competitive and undesirable weed which severely affects crop production, harbors pests and diseases, reduces irrigation efficiency and can reduce product quality through contamination (Moffett and McCloskey, 1998). Leon *et al.* (2003) reported that fresh weight of cotton was reduced by 9 to 42% when grown with *C. rotundus* compared with weed-free controls, soybean fresh weight decreased by 30 to 35% when it emerged simultaneously with *C. rotundus* and 44 to 72% when it emerged 7 days after *C. rotundus*. *C. rotundus* competes with maize and soybean for essential resources and cause significant reduction in the growth and development of these crops. Maize proved to be more susceptible to *C. rotundus* interference than soybean (Tuor and Froud-Williams, 2002). Iqbal *et al.* (2007) reported variable growth suppression of different rice genotypes from *C. rotundus* interference. This weed has been found to produce allelopathic substances which can inhibit the growth of nearby plants (Hierro and Callaway, 2003) and these allelochemicals seems phenolics in nature (Horowitz and Friedman, 1971).

Cyperus rotundus is also the most common weeds in major summer field crops, vegetables and fruit crops in many parts of the world (Peerzada, 2017) and has a variety of means of propagation including seeds, rhizomes and tubers with varying levels of dormancy (Rao, 2000). This makes the management of *C. rotundus* highly difficult. Typical manual or mechanical weed control methods kill only the top growth with little effect on tubers, while very few herbicide options are available for the control of this weed.

Moreover, chemical weed control may enhance human and environmental health risks (Duke *et al.*, 2001). Emerging deleterious effects due to increased reliance on synthetic herbicides in many cropping systems including weed shifts, weed resistance and non-target toxicity (Westcott *et al.*, 1987; Zhang, 2003) requires investigation of environmentally safe and sustainable weed management strategies with reduced cost of production. One potentially valuable managerial control tactic is the use of highly competitive crops especially effective at suppressing weeds including purple *C. rotundus*. The main objective of this study was to assess the suppressive ability of various summer-season crops commonly grown in Pakistan on purple *C. rotundus*. Any negative impacts of *C. rotundus* on the test crops were also evaluated.

Materials and Methods

Study Site

This two-year greenhouse study was conducted at the College of Agriculture, Dera Ghazi Khan, Pakistan (30.03°N and 70.38°E) during May of 2012 and 2013.

Treatments and Crop Husbandry

Seeds of mungbean, cotton, millet, sesame, sorghum, cowpea and groundnut were sown either alone and in mixture with *C. rotundus*. A sole stand of *C. rotundus* was also maintained for comparison. The pots used to grow the crops, weed or crop+weed had a diameter of 32 cm and a depth of 38 cm. Each pot was filled with 27 kg of sandy loam soil from a field with the history of cotton–wheat cropping pattern. Initially, three seeds of each crop were sown in a pot but soon after emergence thinning was done to maintain only one seedling in the center of each pot.

For *C. rotundus* seedlings, its tubers were collected from several cotton fields, mixed to make a composite sample and sown in sand filled tubs in the same day to grow nursery. After two weeks, ten sprouted tubers were sown 2 cm below the soil surface with each of the crop seedlings. The *C. rotundus* tubers were sown randomly around the crop plant.

Agronomic Management

The pots were applied with 4 L water at the time of sowing and later when required. Di-ammonium phosphate (DAP) and urea were applied at 2 and 8 g pot^{-1} respectively. The experiment was laid out in a completely randomized design with four replications. Shoots of *C. rotundus* were counted at 30 and 75 days after sowing (DAS) in order to record its density. The plants were then uprooted and cut at the base to separate roots and shoots. Shoot and root lengths were recorded using a meter rod. Roots were washed with tap water, oven-dried at 70°C until constant weight to determinate dry weight using an electric balance. Similarly, the shoots of *C. rotundus* and crop plants were also dried in an oven until constant weight and weighed using an electric balance. The *C. rotundus* tubers developed in each treatment were determined at 75 DAS by digging the soil. The tubers from each treatment were washed thoroughly with tap water, counted, dried at 70°C until constant weight and weighed. Crop growth inhibition by *C. rotundus* was computed by recording different growth parameters for each crop in the study. The parameters recorded for each crop were shoot and root lengths, shoot and root dry weights, number of branches per plant in branch bearing crops, numbers of pods per plant in leguminous crops, number of bolls in cotton and number of nodule in leguminous crops. Leguminous crop plants were taken out from pots, their roots and nodules were washed with tap water. Fresh nodules were counted and compared to crops grown in monoculture. The effect of *C. rotundus* on crop parameters was determined as inhibition percentage compared with sole crops.

Data Analysis

Data were averaged across the years and subjected to analysis of variance using the software MSTATC (Freed and Eisensmith, 1986) to determine significance of treatment means. Treatment means were separated using Fisher's Protected LSD test (Steel *et al.*, 1997). Differences for any measured parameter were considered significant at 1% probability level. The correlation between different *C. rotundus* parameters was determined by using SPSS.

Results

Effect of Different Crops on Density and Growth of *C. rotundus*

The summer crops in the study had a different effect on the density and growth of *C. rotundus* (Table 1). Moreover, a different response of *C. rotundus* to competing crops was noted at either 30 or 75 days after sowing (DAS). Density reductions ranged from 14–53% at the early growth stage (30 DAS) compared with 45–86% decrease at 75 DAS. At the 30 DAS, mungbean caused the greatest reduction (53%) in *C. rotundus* density followed by sesame (46%). In contrast, at 75 DAS, sesame interference resulted in the highest decrease (86%) in density of *C. rotundus* followed by millet (70%) and

Table 1: Effect of different summer crops on the density and growth of *C. rotundus*

Treatments	Density of CR (No./pot) 30 DAS	Density of CR (No./pot) 75 DAS	Shoot length of CR(cm)	Root length of CR (cm)	Total shoot weight (g) of CR	Total root weight (g) of CR
C. rotundus alone	25.50 a	30.25 a	47.75 a	93.25 a	7.57 a	29.82 a
CR+Mungbean	12.00 f (-53)	11.50 d (-62)	36.50 c (-24)	72.50 c (-22)	4.59 c (-39)	11.50 c (-61)
CR+Cotton	17.25 cd (-32)	16.50 b (-45)	31.50 d (-34)	84.00 b (-10)	2.89 d (-62)	7.45 e (-75)
CR + Millet	18.75 c (-26)	9.00 e (-70)	27.25 e (-43)	67.50 d (-28)	1.98 f (-74)	19.58 b (-34)
CR+ Sesame	13.75 e (-46)	4.25 f (-86)	35.75 c (-25)	32.75 f (-65)	2.23 ef (-71)	3.71 f (-88)
CR+ Sorghum	18.00 cd (-29)	12.25 d (-60)	41.75 b (-13)	72.50 c (-22)	2.67 de (-65)	11.86 c (-60)
CR+ Cowpea	16.25 d (-34)	14.00 c (-54)	14.25 f (-70)	92.50 a (-1)	5.40 b (-29)	9.08 d (-70)
CR+ Groundnut	22.00 b (-14)	9.25 e (-69)	29.00 e (-39)	61.75 e (-34)	4.74 c (-37)	4.47 f (-85)
LSD at 0.05	1.7	1.72	2.2	4.5	0.62	1.6

Means not carrying same letters in each column differ significantly at $p \leq 0.05$

Values in parentheses show the percentage reduction (-) in density or a growth parameters of *C. rotundus* through crop competition; DAS = Days after sowing; *Cyperus rotundus* (CR); No = Number

Table 2: Correlations among different parameters of *C. rotundus*

	Shoot length	Root length	Shoot weight	Root weight	Tuber numbers pot^{-1}	Tubers weight pot^{-1}	Per tuber weight
Plant density	0.424	0.781*	0.769*	0.763*	0.876**	0.912**	-0.611
Shoot length		-0.089	0.164	0.463	0.264	0.383	0.174
Root length			0.615	0.531	0.693	0.676	-0.740*
Shoot weight				0.498	0.937**	0.880**	-0.838**
Root weight					0.746*	0.839**	-0.386
Tuber density						0.970**	-0.828*
Tubers dry weight							-0.707*

*, **Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

groundnut (69%). Cotton was least effective in suppressing *C. rotundus*, however, the effect was significant compared with *C. rotundus* grown alone. Plant density of *C. rotundus* was positively correlated with its root length, shoot and root biomass, number and weight of tubers per pot and weight per tuber (Table 2).

Effect of Different Crops on Shoot Length and Dry Weight of *C. rotundus*

When grown in mixture with test crops, significant reductions in *C. rotundus* shoot length (13-70%) and shoot dry weight (29-74%) occurred compared with *C. rotundus* plants grown alone (Table 1). Highest reductions in shoot length of *C. rotundus* were observed when grown with cowpeas (70%) followed by millet (43%) and groundnut (35%). Sorghum was least effective in suppressing *C. rotundus* shoot length. *C. rotundus* shoot weight reduction trends differed compared with its shoot length decreases. Highest *C. rotundus* shoot weight decreases were recorded when grown with millet (74%) followed by sesame (70%) and sorghum (65%). Cowpea was least effective in decreasing *C. rotundus* shoot biomass. The legume crops including cowpea and groundnut were comparatively less suppressive of *C. rotundus* compared to non-legume crops. *C. rotundus* dry weight was positively correlated with plant density, tuber number per pot, tuber weight per pot and negatively correlated with per tuber weight (Table 2).

Effect of Different Crops on *C. rotundus* Root Length and Root Dry Weight

Root length and dry weight of *C. rotundus* were significantly suppressed by different crops except the nearly neutral effect of cowpea on root length (Table 1). The greatest reductions in *C. rotundus* root length occurred when grown with sesame (65%) followed by groundnut (34%). Cotton and cowpea were least effective in decreasing root length. The greatest reductions in *C. rotundus* root dry weight occurred when grown with sesame (88%) and groundnut (85%). The level of inhibition in root dry weight was more pronounced compared with root length. *C. rotundus* root length was positively correlated with plant density and negatively with weight per tuber (Table 2).

Effect of Crops on Tubers of *C. rotundus*

Crops significantly suppressed the total number of *C. rotundus* tubers per pot and tuber dry weight compared with *C. rotundus* grown alone (Table 3). Growing the weed with a sesame crop resulted in 84% reduction in the number of tubers produced followed by sorghum with a 75% reduction in tuber production relative to the weed-only treatment. Suppression of *C. rotundus* tubers varied from 43% (cowpea) to 47% (mungbean). In general, the effect of the various crops on tuber weight per pot was similar to observed for total tuber production. In general, results of *C. rotundus* tuber weight varied widely with other parameters measured. For example, the highest weights per tuber were observed in *C. rotundus* only treatments and mungbean, cowpea crop treatments. The heaviest tubers were recorded when *C. rotundus* was grown with a sesame and sorghum crop. Tuber numbers were positively correlated with *C. rotundus* plant density, shoot and root weights and tuber weight per pot, but negatively with weight per tuber

Table 3: Effect of competition from different summer crops on density and dry weight of *C. rotundus* tuber

Treatments	Density(No./pot)	Dry weight (g/pot)	Weight per tuber (g)
C. rotundus alone	124a	14.75a	0.119 e
PNS + Mung	66.75c (-47)	8.10 bc (-45)	0.123 e (+4)
CR+ Cotton	38.00 e (-69)	6.48 f (-56)	0.171 d (+43)
CR+ Millet	38.00 e (-69)	7.21 de (-51)	0.190 c (+59)
CR+ Sesame	19.50 g (-84)	4.40 g (-70)	0.224 a (+90)
CR+ Sorghum	30.50 f (-75)	6.59 ef (-55)	0.216 b (+82)
CR+ Cowpea	70.25 b (-43)	8.25 b (-44)	0.117 e (-1)
CR+ Groundnut	45.50 d (-63)	7.52 cd (-49)	0.165 d (+39)
LSD at 0.05	2.95	0.695	0.007

Means with different letters in a column differ significantly at $p \leq 0.05$
Values in parentheses show the percentage suppression (-) or stimulation (+) compared to the control treatment where *C. rotundus* was grown alone
CR: *Cyperus rotundus*

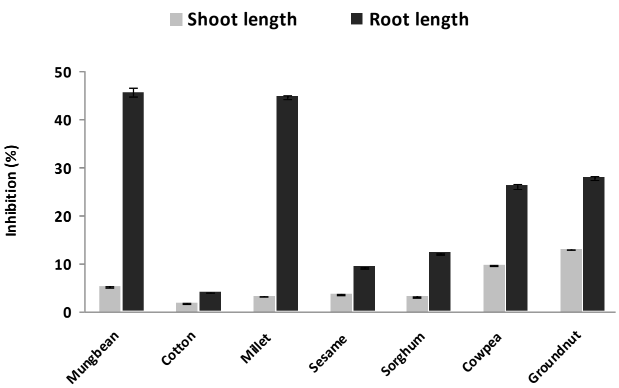

Fig. 1: Effect of *C. rotundus* on shoot and root length of different summer crops

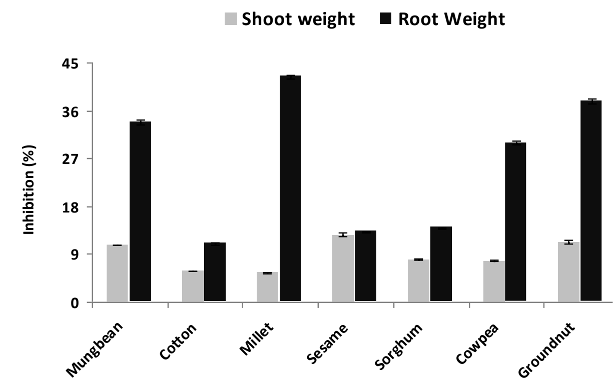

Fig. 2: Effect of *C. rotundus* on shoot and root dry weight of different summer crops

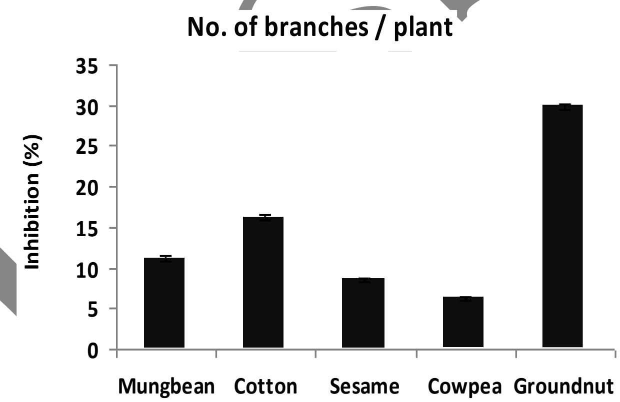

Fig. 3: Effect of *C. rotundus* on number of branches per plant of summer crops

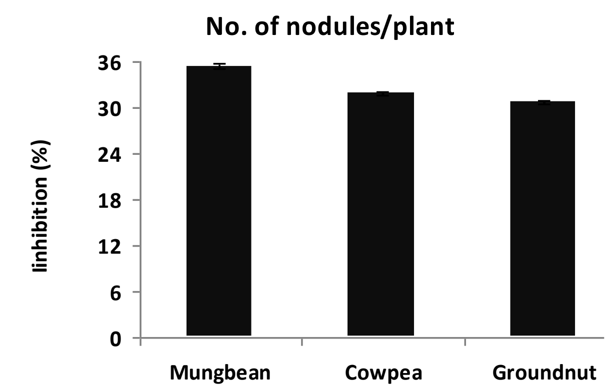

Fig. 4: Effect of *C. rotundus* on number of nodules per plant of summer-season leguminous crops

(Table 2). Tuber weights per pot were positively correlated with plant density, shoot and root weight, and number of *C. rotundus* tubers, however, negatively correlated with the tuber weight. Weight per tuber was negatively correlated with root length, shoot weight and tuber weight per pot (Table 2).

Effect of *C. rotundus* on Crop Growth

The impact of *C. rotundus* on crop growth and yield was relatively lower compared with the negative effect of crops had on *C. rotundus* growth and tuber weight. Negative effect of *C. rotundus* was stronger on plant height of leguminous crops than the non-legume crops (Fig. 1). Moreover, the roots of different crops received a more negative effect from *C. rotundus* than did their shoots. The highest decrease in root length was observed in mungbean followed by millet (Fig. 1). Cotton and sesame root lengths were least suppressed by *C. rotundus*. Maximum inhibition in shoot weight of *C. rotundus* was recorded in sesame followed by groundnut and mungbean (Fig. 2). Cotton and millet shoot weights were least affected. Root dry weight of crops was more severely affected by *C. rotundus* than their shoot dry weight. The highest reductions in root dry weight were observed in millet followed by groundnut and mungbean. Cotton root dry weight was least affected by *C. rotundus* followed by sesame and sorghum. The highest reduction in the number of branches was recorded in groundnut (Fig. 3). Suppression of *C. rotundus* caused significant suppression of nodulation in the studied crops, this suppression was highest in mungbean followed by cowpea and groundnut (Fig. 4).

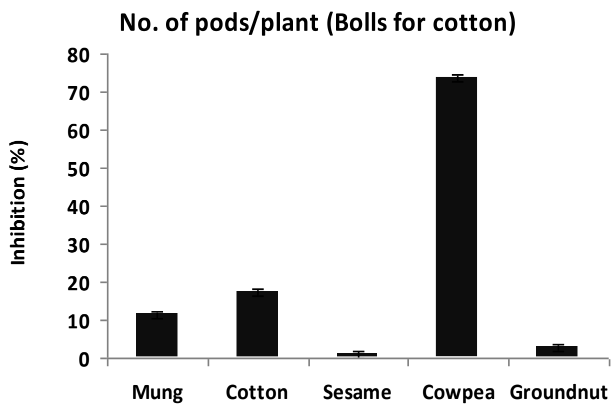

Fig. 5: Effect of *C. rotundus* on number of pods (bolls for cotton) per plant of summer crops

A significant reduction in number of pods per plant was recorded due to *C. rotundus* infestation, this reduction was highest in cowpeas (74%) followed by mungbean, whereas lowest inhibition was noted in sesame. *C. rotundus* infestation caused significant reduction (17%) in number of cotton bolls (Fig. 5).

Discussion

All crops effectively suppressed the *C. rotundus* density, dry matter yield and tuber production. The high levels of *C. rotundus* suppression for growth and reproductive traits caused through competition by different crops is comparable with the *C. rotundus* suppression caused either by herbicide or a physical weed control method (Iqbal *et al.*, 2007; Bajwa, 2014). The suppression of *C. rotundus* used by various crops in the study was either due to (1) competition (Iqbal *et al.*, 2007; Ramesh *et al.*, 2016; Ali *et al.*, 2017), or (2) allelopathy (Matloob *et al.*, 2010; Cheema *et al.*, 2013). However, a combined effect of both of these factors may also play a role to suppress the weeds.

Crop allelopathy may have played an important role inhibiting germination of tubers and growth of *C. rotundus* plants (Farooq *et al.*, 2011; Jabran *et al.*, 2015). Roots were more negatively affected as compared to shoots, mainly because roots are the site of greatest activity within the soil rhizosphere during crop growth (Bertin *et al.*, 2003). Moreover certain crop plants have the ability to produce and exude allelochemicals into their surroundings which suppress weed growth (Jabran and Farooq, 2013; Jabran *et al.*, 2015; Yazlik and Uremis, 2016; Qureshi and Arshad, 2017). Although not directly assessed in this study, the allelopathic potential of sorghum, millet and sesame is well documented (Weston and Duke, 2003; Dayan *et al.*, 2010). The allelopathic effect of sesame on *C. rotundus* has also been reported (Kumar and Varshney, 2008; Kumar *et al.*, 2011). It is possible that allelopathic effects of studied crops potential caused high suppression of *C. rotundus* in this study.

Although the deleterious effect of non-legume crops on *C. rotundus* performance can be attributed to resource depletion in addition to their possible allelopathic effects and the suppressive effects of leguminous crops may be of important interest. Velvet bean (as living cover crop) caused 68% reduction in weed biomass (Caamal-Maldonado *et al.*, 2001). Rhizosphere soils in the mungbean crop contained high concentrations of allelochemicals *e.g.*, *p*-hydroxybenzoic and salicylic acids than non rhizospheric soil (Pareek and Gaur, 1973).

Many researchers have indicated that crops can suppress weeds by more effective use of resources (Zuofa *et al.*, 1992). A new concept of allelochemically-enhanced-competition as a mechanism for such observed suppression of weed growth has been proposed earlier (An *et al.*, 2007). These workers suggested that allelopathy and competition may not be two distinct processes as generally believed but that increased competitiveness of crop plants may be significantly enhanced by their release of allelochemicals; hence the term allelochemically-enhanced-competition has been coined.

C. rotundus growth was effectively suppressed by all crops, the crops benefited from less intense competition from *C. rotundus* as there was less negative impact on crop growth *i.e.*, 2-46%, while suppression of weed growth was up to 88%. This finding provides further evidence that to maximize benefits of weed suppression by crops, it is important to select highly competitive crops especially in situations where other effective control tactics are not available.

Conclusions

All the crops effectively controlled *C. rotundus* density, dry matter yield and tuber production. The suppression in this weed was up to 88% of control which is comparable with those achieved by herbicides and hand weeding. Crop competition and allelopathy may play an important role for better weed management. Roots are the site of greatest activity in soil atmosphere during crop growth and can influence the neighbouring weed plants.

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