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Purple nutsedge management with allelopathic sorghum

Z. A. CHEEMA, M. N. MUSHTAQ, M. FAROOQ*, A. HUSSAIN[2] and
ISLAM-UD-DIN[1]

Department of Agronomy
University of Agriculture, Faisalabad-38040, Pakistan
E. Mail: farooqcp@gmail.com

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ABSTRACT

Purple nutsedge (*Cyperus rotundus* L.) is most troublesome and noxious weed. Sorghum allelopathy has the potential to suppress many weeds; hence, this study was done to explore the potential of sorghum allelopathy in purple nutsedge management in pot culture and field studies. In laboratory bioassay, Sorgaab (sorghum water extract) 0, 5, 50 and 100% was compared to acetachlor (Dechlor 50-EC) and weedy check. In field trial, irrigated and rainfed sorghum cv. JS-263 was harvested at maturity and incorporated into the soil as under (i) Control (without sorghum), (ii) Pre-flowering stage, (iii) Uprooted at maturity, (iv) Roots at maturity, (v) Roots+stem at maturity, (vi) Roots+leaves at maturity and (vii) Whole plants at maturity. Sorghum treated plots were sown with wheat or kept fallow in the following summer season. Laboratory study showed that Sorgaab (100%) was the best treatment in suppressing the shoot length and dry weight of purple nutsedge. Field study showed ~100% reduction in purple nutsedge population. Three allelochemicals viz., m-coumaric acid, caffeic acid and chlorogenic acid were identified in sorghum by gas chromatography.

Key words: Allelochemicals, allelopathy, *Cyperus rotundus* L., purple nutsedge, *Sorghum bicolor* L.

INTRODUCTION

Purple nutsedge (*Cyperus rotundus* L.) is perennial sedge, one of 10 worst weeds, found in 52 crops in 92 countries (2,20) causes yield reduction (23-89%) in crops (11). In Pakistan, it is a serious problem in most of the crops. Sedges propagate through rhizomes, tubers and seeds, hence mechanical methods kill only the top growth with little effect on the tubers, nevertheless translocated herbicides are effective in controlling such weeds. However, use of synthetic herbicides is (i) posing serious threat to environment and (ii) resulting in development of herbicide resistant weed bio-types (1,9). The need to develop environmental friendly and cost effective weed control strategies as alternative of herbicides has been realized by the researchers worldwide.

Allelopathy has emerged as natural technique of weed management in recent years (16,26). The allelopathic plants/crops affect the growth of weeds through release of allelochemicals (1,24). The allelopathic crops are used as mulch, cover crops (5,22), soil incorporation (12) or included in crop rotation (17) to manage the target weeds. Duke *et al*. (6) suggested the possible use of plant allelochemicals for weed management like the

*Correspondence Author; [1]Department of Mathematics and Statistics, University of Agriculture, Faisalabad-38040, Pakistan; [2]Nuclear Institute for Agriculture and Biology (NIAB), Faisalabd-38040, Pakistan.

herbicides. Sorghum (*Sorghum bicolor* L.) is a potential allelopathic plant and posses many water soluble allelochemicals which are easily extracted (5,24). Its all parts (roots, herbage and germinating seeds) release allelochemicals as glycosides and phenolic acids, which inhibits the growth of weeds (7,10,27). The aqueous extract of field grown sorghum herbage and roots inhibits the cress (*Lepidium sativum* L.) germination and growth (15). Sorgaab foliar spray controls the weeds (*Phlaris minor* L., *Avena fatua* L., *Rumex dentatis* L. *Chenopodium album* L. and *Fumaria indica* L.) by ~39-49 % (4). Sorghum-sudangrass hybrid cover crop provides weed control due to release of phenolic acids from decomposing residues (27). Many allelochemicals (benzoic acid, p-hydroxy benzoic acid, vanillic acid, m-coumric acid, p-coumaric acid, gallic acid, ferulic acid, dhurrin, p-hydroxybenzaldehyde and sorgoleone) have been identified in the sorghum (8,18). The foliar application of sorghum water extract, soil incorporation of sorghum, sorghum mulch or as cover crop inhibits the weeds population and dry weight (3,4,5). Nevertheless, sorghum allelopathy has not been explored for purple nutsedge management extensively. This study was therefore, conducted to explore the potential of allelopathic sorghum for purple nutsedge management in laboratory and field conditions.

MATERIALS AND METHODS

Laboratory bioassays were conducted in Weed Science and Allelopathy Laboratory, while field experiments were done in Agronomic Research Area, on loamy soil. The weather traits differed during three years of experimentation.

Identification of allelochemicals

Sorghum material was air dried and crushed with crusher (Germany crusher) to pass through 2 mm sieve. Ten g of air dried ground sample of sorghum plants was hydrolyzed with 100 ml of 2N NaOH in an autoclave for 30 min. The mixture was shaken for 15 min and then filtered. The filtrate was adjusted to pH 2.0 using dilute HCl. The solution was extracted with 300 ml ether thrice. The whole ether fractions were thereafter, extracted with 300 ml 5% $NaHCO_3$ thrice and the ether fraction was discarded. The alkaline aqueous portion was acidified to pH 2.0 using dilute HCl and then contents were re-extracted with 330 ml ether three times. The ether was dried over anhydrous Na_2SO_4 and evaporated to dryness below 45^{o}C. The residue was used for identification of phytotoxins. The individual allelochemicals in sorghum were identified by gas chromatograph (Hitachi 163) following Kuwatsuka and Shindo (14).

Pot culture

Purple nutsedge sprouted tubers of uniform size were collected early in the morning from Agronomy Research Farm. The shoots were chopped and then 5 tubers were planted in pots (9 × 9 cm) and filled with 500 g sandy loam soil. The pots were kept at room temperature (32^{o}C±2) in completely randomized design (CRD) with four replications. Sorgaab was prepared as per Cheema and Khaliq (4). Treatments comprised of (i) Sorgaab (100%), (ii) Sorgaab 50 % and (iii) Sorgaab 5%, (iv) Acetachlor (1900 g a.i. ha $^{-1}$) and (v) weedy check as control (Sorgaab 0%). Twenty five ml Sorgaab was applied per pot, when seedlings of purple nutsedge had established and started active growth. Data on shoot length were recorded daily for 13 days, while fresh weight of purple nutsedge was recorded 15 days after sowing (DAS). The seedlings were dried in oven at 70^{o}C for 72 h to record dry weight.

Field experiment

A 3-years field study was conducted with 3-factors in split-split plot design. There were main plot treatments: 2 [(i) Irrigated and (ii) Rainfed sorghum], subplots: 2 [(i) Sorghum-wheat and (ii) Sorghum-fallow, Sub-sub plots: 7 treatments of sorghum biomass incorporation in soil [(i) Control (without sorghum), (ii) Pre-flowering stage, (iii) Uprooted at maturity, (iv) Roots at maturity, (v) Roots+stem at maturity, (vi) Roots+leaves at maturity and (vii) Whole plants at maturity)]. The study was conducted in the same field for 3-years and replicated thrice. Sorghum cv. JS-263 was sown with drill at 25 kg seeds ha^{-1} in 45 cm spaced rows. Sorghum growing in one plot received irrigation, while the other one, received only rainfall. The crop was harvested and chopped with an electric chopper, then incorporated into the soil as per treatments, while no-sorghum plots were maintained as control. Three to five irrigations were applied to irrigated sorghum. Population of purple nutsedge was recorded from the respective plots from 1 m^{2} area, before the start of next year experiments from selected area in each plot at 95, 92 and 85 days after incorporation of sorghum during 1st, 2nd and 3rd year respectively.

Statistical analysis: The data were analyzed statistically using fisher's analysis of variance technique while multiple comparisons among treatment means was made using least significance difference test (LSD) at $P \leq 0.05$ (23).

RESULTS

Different peaks of the chromatograph were compared with standards to identify the compounds responsible for phytotoxic action. Nine allelochemicals (benzoic acid, p-hydroxy benzoic acid, vanillic acid, m-coumric acid, p-coumaric acid, gallic acid, caffeic acid, ferulic acid and chlorogenic acid) were identified in the sorghum (Fig. 1). Three compounds were new, while, 6 have been previously identified.

Pot culture

All treatments significantly suppressed the purple nutsedge shoot length than control (Fig. 2). The application of Sorgaab 100% caused maximum suppression of purple nutsedge followed by acetachlor application and 50% Sorgaab. Likewise, dry mass production of purple nutsedge was also inhibited by Sorgaab application over the control (Fig. 3). Sorgaab used as original was most effective (75% reduction in dry matter of purple nutsedge), followed by Sorgaab 50% (60 % reduction in shoot dry weight). Nonetheless, acetachlor also decreased the purple nutsedge dry weight of (75%) (Fig. 3).

Field experiment

All treatments significantly decreased the purple nutsedge population during

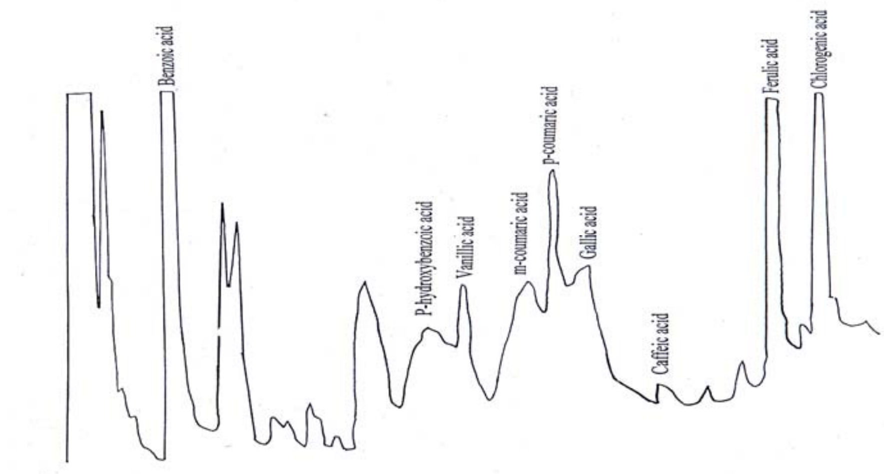

Figure 1. Chromatogram of allelochemicals identified in sorghum.

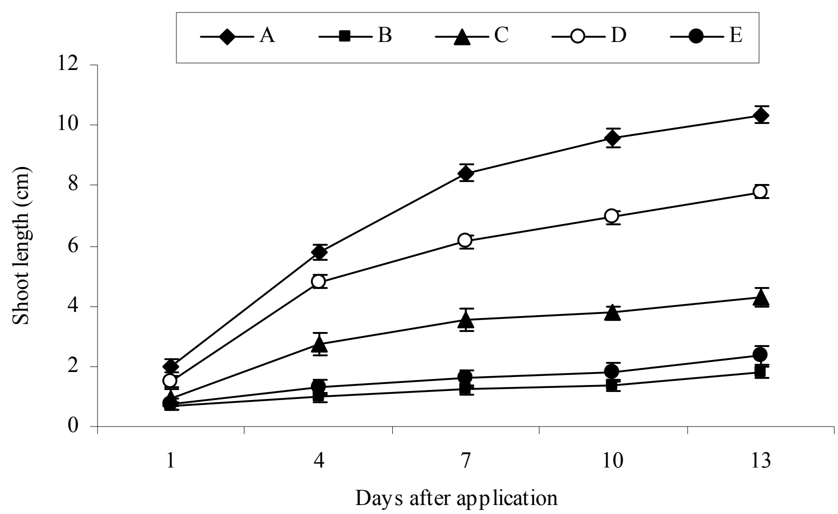

Figure 2. Effects of Sorgaab on shoot length of purple nutsedge. (A) Control; (B) Sorgaab (100%); (C) Sorgaab (50%); (D) Sorgaab (5%); (E) Acetachlor at 1900 g a.i. ha^{-1}

3-years study, except whole sorghum incorporated at maturity and sorghum roots incorporation in irrigated wheat during 2^{nd} and 3^{rd} years, respectively, compared with control (Fig. 4). During the study period, there was less density of purple nutsedge in wheat fields than in fallow fields.

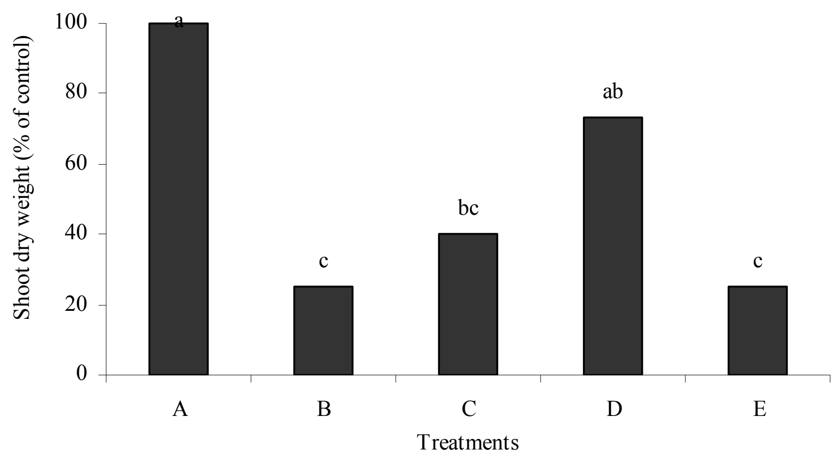

Figure 3. Effects of Sorgaab on shoot dry weight of purple nutsedge. (A) Control; (B) Sorgaab (100%); (C) Sorgaab (50%); (D) Sorgaab (5%); (E) Acetachlor at 1900 g a.i. ha^{-1}

In first year, incorporation of irrigated sorghum in wheat was more effective in controlling purple nutsedge. Its incorporation at pre-flowering, roots+stem at maturity, roots+leaves at maturity and whole sorghum at maturity, drastically reduced the purple nutsedge density in wheat by 100% than control. Likewise, soil incorporation of rainfed sorghum roots+stem at maturity, roots+leaves at maturity and whole sorghum at maturity, also reduced the purple nutsedge density in wheat by 100%.

In second year, incorporation of rainfed sorghum roots+stem at maturity and roots+leaves at maturity, suppressed purple nutsedge population in wheat by 100% compared to control. Nonetheless irrigated sorghum roots+stem incorporated at maturity inhibited purple nutsedge density by 74%. While in third year, whole rainfed sorghum incorporated at maturity in wheat inhibited purple nutsedge population by 95%, while, whole irrigated sorghum incorporated at maturity under fallow conditions suppressed purple nutsedge density by 85% (Fig. 4).

DISCUSSION

In this study, we have identified 3 new allelochemicals (m-coumaric acid, caffeic acid and chlorogenic acid) along with 6-previously identified allelochemicals, which proves the potent phytotoxic effect of sorghum against weeds. Presence of six allelochemicals has already been reported (3,8,18,27).

The Pot culture showed significant inhibition of purple nutsedge shoot length and biomass with foliar spray of Sorgaab. The Sorgaab 100% was more effective, while its further dilution, proportionately decreased its effect. This indicates that higher concentration was more effective possibly due to presence of higher amount of allelochemicals (5).

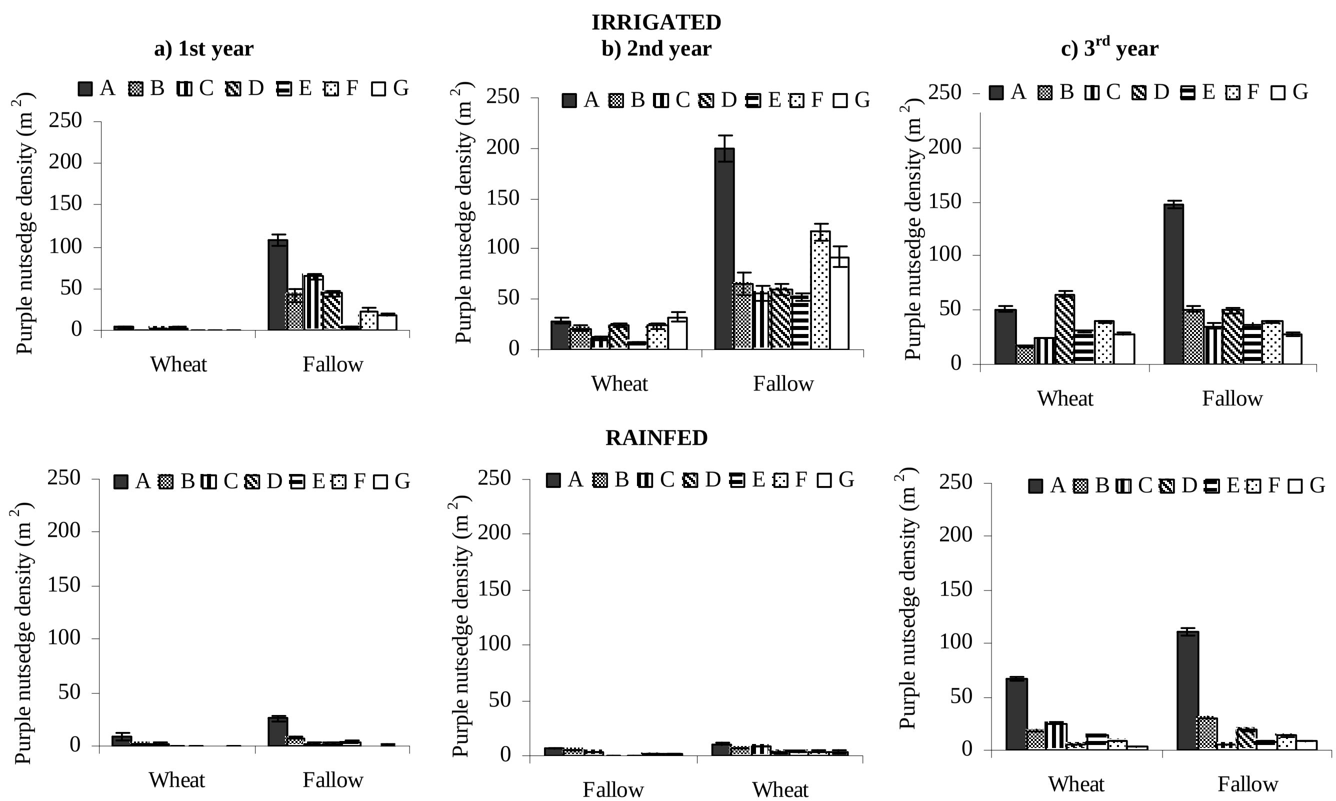

Figure 4. Interactive effects of irrigation, wheat and sorghum on density of purple nutsedge. A: Control (no sorghum), B: Sorghum incorporated at pre-flowering, C: Sorghum uprooted at maturity, D: Sorghum roots incorporated at maturity, E: Sorghum roots+stem incorporated at maturity, F: Sorghum roots+leaves incorporated at maturity and G: Whole sorghum incorporated

Effectiveness of allelopathy under field conditions and its use to substitute herbicides is often questioned. The production and release of allelochemicals in plant and response of the recipient species is dependent on many factors including radiation, mineral deficiency, water stress, temperature, allelopathic agents, plant age, genetics and pathogen attack (13,21). Present studies provide a novel example of natural control of purple nutsedge to a considerable extent with sorghum under field conditions. The 3-years field experiments, showed consistent results, purple nutsedge population was inhibited by allelopathic treatments, though there was variation in weather attributes amongst the years. Irrigated sorghum was more effective in suppressing purple nutsedge, because it produces more biomass and hence, released more allelochemicals in the soil, which suppresses the population of purple nutsedge (5,12).

Purple nutsedge population was less in wheat fields than fallow fields, which showed weed suppression by weed-crop competition. In wheat planted fields, the crop competed with purple nutsedge for growth factors resulting in comparatively less population of purple nutsedge (Fig. 4). Whole sorghum and roots + stem incorporated at maturity gave maximum reduction in purple nutsedge density in all 3-years of study. Grain sorghum inhibits the growth of surrounding weeds during the following growth season (7). Panasuik *et al.* (19) and Hoffman *et al.* (10) also reported potential of sorghum seed and seedlings to inhibit the weed growth. Likewise, spring grown sorghum residues provided 90% reduction in weeds in summer grown soybeans (25). The inhibition of purple nutsedge with sorghum under field conditions and Sorgaab in pot culture shows the herbicidal potential of sorghum, which may be attributed to presence of several water soluble phytotoxins.

Thus sorghum allelopathy can be employed effectively to manage purple nutsedge under field conditions. The phenomenon of allelopathy appeared as a natural weed control method, which can be exploited to reduce the herbicides use for eco-friendly sustainable crop production.

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