BIOASSAY OF ALLELOPATHIC POTENTIAL OF BERMUDAGRASS AND SORGHUM ON GERMINATION AND RELATED TRAITS OF WEEDS ASSOCIATED WITH RICE

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ABSTRACT

With growing concern towards human health and ecological concerns related to prolonged use of herbicides, research is undergoing globally for alternate weed managing methods. Allelopathy is one of the very efficient methods for management of weeds. Experiment was conducted during 2016 and repeated in 2017 under laboratory conditions in Kharif (summer) season using completely randomized design for allelopathic potential assessment of bermudagrass (*Cynodon dactylon* L.) and sorghum (*Sorghum bicolor* L.) with 03 replicates. The treatments under study comprised: control (check), bermudagrass & sorghum root & shoot powders @ 15 and 30 g kg^{-1} soil as well as water extracts @ 15 and 30 ml kg^{-1} soil. It is obvious from the present data that allelopathic plants powders & water extracts caused significant adverse effects on tested weeds i.e. Sawari (*Echinochloa colonum* L.), Saon (*Echinochloa crusgalli* L.) and Kabah (*Cyperus rotundus* L.). Bermudagrass and sorghum water extracts exhibited strong allelopathic efficacy on germination, roots & shoots length, as well as fresh & dry biological weight of weeds included under study. It is further argued that greater inhibitory effects on weeds were caused by extracts prepared from bermudagrass and sorghum in comparison with their powders. Hence, it is evident from the results that bermudagrass & sorghum materials possess phytotoxic potential which can suppress growth of target plant. This allelopathic herbage could be utilized by soil incorporation or extract for weed management in rice as environment friendly strategy.

Keywords: Allelopathic potential, germination, growth, sorghum, bermudagrass, rice weeds

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INTRODUCTION

Rice production is the backbone in agricultural sector of sub-tropical and tropical countries, including Pakistan (Nazir *et al*., 2022). One of the major threats to sustainable crop production is infestation of weeds in crop field (Uno *et al*., 2021). Weeds compete with the crop plants for moisture, nutrients, sunlight, spacing and CO_2 (Rana *et al*., 2020), causing heavy yield losses and deterioration of quality of produce (Hosoya and Sugiyama, 2017) and thus increase the crop production expenses (Jabran *et al.,* 2010). The weeds with narrow leaves i.e. jungle rice, johnson grass, bermudagrass and purple nutsedge have been found to cause the severe yield losses to narrow leaves crops such as rice because of similar morphological characteristics and growth factors requirements (Ali *et al.,* 2013). Yield losses in crops due to weeds depend on several factors such as weed emergence time, weed density, type of weeds, and crops, etc. If left uncontrolled, weeds can result in 100% yield loss (Chauhan, 2020). The utilization of herbicides for long time causes the resistance to herbicides in weeds, weakens the soil quality, food, and water (Hicks *et al.,* 2018). With the growing concern towards human health and ecological concerns related to prolonged use of herbicides, research is undergoing globally for alternative weed management methods (Farooq *et al*., 2020). Using the potential of allelopathy of several plant species for weed management is one of the examples of approaches (Iqbal and Cheema, 2009). Macias *et al.* (2019) suggested that the production of one or many biochemicals influencing the germination, development, existence, and breeding of other organisms is called allelopathy and these biochemicals are known as allelochemicals. They can influence beneficially or detrimentally on the target organisms and the community. The crops with allelopathic potentials possess certain compounds which have inhibiting power in their underground and above ground parts (Tesio and Ferrero, 2010) in varying concentrations. The allelochemicals' impact on plants can be diverse including alterations and ultimately impacting the development of targeted plants (Matos *et al.,* 2021).

Sorghum (*Sorghum bicolor* L.) consists of allelopathic compounds in its aerial and underground parts. The mature sorghum plants contain many allelochemicals which depress weed growth and decrease their population (Besancon *et al.,* 2020). The root of sorghum contains the compounds like Benzoic Acid, Caffeic Acids, Ferulic Acid, Gallic Acid, M-Coumaric Acid, P-Coumaric Acid, P-Hydroxybenzaldehyde, P-Hydroxybenzoic Acid, Protocateuic Acid, Sorgoleone Syringic Acid, and Vanillic Acid (Hussain *et al.,* 2021).

Bermudagrass (*Cynodon dactylon* L.) is well known as worst weed that is found almost everywhere in the world and it consists of the fourth most allelopathic compounds (Zhang *et al*., 2022). Due to its compatibility for water, nutrients, space and the soil oxygen, bermudagrass is often an effective colonizer (Chen *et al*., 2021). Bermudagrass contains many allelochemicals such as Caffeic, Ferulic, P-Coumaric, P-Hydroxybenzoic Syringic Acids and Vanillic (Mahmoodzadeh, 2010). These phenolics represent the effect of allelopathy which supports the statement that phytotoxicity of bermudagrass may be because of the occurrence of phenolic compounds (Zhang *et al*., 2022). Experiments under laboratory are thought to be indispensable and useful to investigate the allelopathic potential of any plant (Tibugari *et al*., 2020). The germinability and growth traits of test plants are depressed when they placed under allelopathic compounds (Nouri *et al*., 2012). Phytotoxic action of material having allelopathic potential varies with the type of plant part, its age, genotype, environmental factors, and weed species under target (Farooq *et al*., 2017). Hence, the present study was based on the objective to determine the allelopathic

impact of bermudagrass and sorghum water extract on germination and related growth traits of weeds associated with rice.

MATERIALS AND METHODS

The laboratory experiment was performed during summer 2016 at the Weed Science & Allelopathy Laboratory, Sindh Agriculture University, Tandojam. The experiment was repeated during 2017 for accuracy of results. The average data of two years research has been presented in tables used for statistical analysis. The experiment was performed under completely randomized design for allelopathic potential assessment of bermudagrass (*Cynodon dactylon* L.) and sorghum (*Sorghum bicolor* L.) with 03 replications. The boxes of 9 cm x 5 cm x 3cm size were used. The quantity of soil used was 5 kg box^{-1} and then moistened with water. Three rice associated weeds viz. Sawari (*Echinochloa colonum* L.), Saon (*Echinochloa crusgalli* L.), Kabah (*Cyperus rotundus* L.) were tested in contrast to allelopathic inhibiting efficacy of roots and shoots powders and extracts of bermudagrass and sorghum. The seeds/ propagules (as the case may be) of test weeds were sown in 1st week of May. The boxes were placed at normal temperature of room. The treatments under study comprised: untreated (check), bermudagrass water extract @ 15 ml kg^{-1} soil, bermudagrass water extract @ 30 ml kg^{-1} soil, sorghum water extract @ 15 ml kg^{-1} soil, sorghum water extract @ 30 ml kg^{-1} soil, bermudagrass powder soil incorporation @ 15 g kg^{-1} soil, bermudagrass powder soil incorporation @ 30 g kg^{-1} soil, sorghum powder soil incorporation @ 15 g kg^{-1} soil and sorghum powder soil incorporation @ 30 g kg^{-1} soil.

Preparation and Application of Allelopathic Crops Water Extract

The allelopathic material of bermudagrass and sorghum and test weeds propagation material was gathered from nearby agricultural field. These allelopathic plants were obtained at peak of flowering stage. The herbage of bermudagrass and sorghum was cut into small (2 cm) pieces, kept on ground for drying under sun and finally through grinder converted to the powder. To prepare water extract, the chops of bermudagrass and sorghum were soaked in water for twenty-four hours. In order to concentrate it twenty times the water extracts, they were filtered and boiled at 100ºC on a gas burner. The prepared extract was mixed with water and applied on sand immediately after sowing. As regards, incorporation of powder in soil, the powders of sorghum and bermudagrass were mixed before sowing of weeds thoroughly with soil. The canal water was applied to boxes as and when needed. The seedlings were counted for germination (%) and harvested along with roots at the age of twenty days. Immediately after uprooting, the shoot and root length (cm) as well fresh biomass (g) was measured. The seedlings were then kept in the oven for seventy-two hours @ 70ºC and then dry biomass (g) was measured.

STATISTICAL ANALYSIS

The average data of two years (2017 and 2017) study was subjected to analysis of variance technique using computer software Statistix 8.1 version (Statistix, 2006). The test of least significant differences was performed for the comparison of treatments statistically.

RESULTS AND DISCUSSION

Germination (%)

It is clear from the Table-1 that extracts and powders of bermudagrass and sorghum resulted in considerable (p<0.05) inhibition in weeds germination. For *Echinochloa colonum* least germination 54.5% was noted in extract of sorghum @ 30 ml kg^{-1} soil followed by 59.1% in extract of sorghum @ 15 ml kg^{-1} soil. Bermudagrass extract @ 30 and 15 ml kg^{-1} soil ranked 3rd and 4th in inhibitory efficacy resulting in 63.6 and 68.2% germination, respectively. In case of

Echinochloa crusgalli, minimum germination 50.7% was recorded under extract of sorghum @ 30 ml kg^{-1} soil whereas extract of sorghum @ 15 ml kg^{-1} soil and extract of bermudagrass @ 30 ml kg^{-1} soil ranked 2nd and 3rd in allelopathic effect with respective seed germination of 55.8 and 60.9%. Extract of sorghum @ 30 and 15 ml kg^{-1} soil as well as extract of bermudagrass @ 30 ml kg^{-1} soil resulted in lower 51.6, 56.2 and 60.9% germination, respectively for *Cyperus rotundus*. An analysis of the above data confirmed that the bermudagrass and sorghum have a suppressive allelopathic impact on the germination of targeted weeds. Sorghum plant has very important allelopathic properties whereby it generates and releases various biochemicals from different parts such as stems, root hairs and grains. The finding of many researchers have shown that sorghum is an strong allelopathic plant which decrease the physiological traits and growth of plants growing nearby and also weeds which grow at the same time or later on in the field (Hussain *et al*., 2021). Nouri *et al*. (2012) concluded that when the plants with sensitivity are treated with allelochemicals, the weeds germination is significantly reduced. The inhibiting power of bermudagrass and sorghum was variable and form specific. The higher inhibiting effects of extracts on weeds germination may be attributed to their solubilized and available readily form which perhaps caused adverse effects on seedling radicles and suppressed uptake of water and plant nutrients, content of chlorophyll and finally photosynthesis. The action mode of allelochemicals involves different mechanisms like suppression in seed germination rate and percent (Hussain *et al*., 2014). Extract of allelopathic plants proved more suppressive than other forms because in extract allelopathic compounds are dissolved and readily available (Hozayn *et al*., 2011). Sorghum roots, leaves and stems aqueous extracts decreased significantly the germination percent of weed *Echinochloa colonum* (Jesudas *et al*., 2014).

Table 1. Effect of bermudagrass and sorghum extracts and powder soil incorporation on germination (%) of rice associated weeds

Treatments	***Echinochloa colonum***	***Echinochloa crusgalli***	***Cyperus rotundus***
T_1 = Untreated (Check)	90.5 a	91.4 a	88.4a
T_2 = Bermudagrass water extracts: 15 ml kg^{-1} soil	68.2 f	66.0 f	65.6 f
T_3 = Bermudagrass water extracts: 30 ml kg^{-1} soil	63.6 g	60.9 g	60.9 g
T_4 = Sorghum water extracts: 15 ml kg^{-1} soil	59.1 h	55.8 h	56.2 h
T_5 = Sorghum water extracts: 30 ml kg^{-1} soil	54.5 i	50.7i	51.6 i
T_6 = Bermudagrass powder soil incorporation: 15 g kg^{-1} soil	86.4 b	86.4 b	84.2 b
T_7 = Bermudagrass powder soil incorporation: 30 g kg^{-1} soil	81.9 c	81.3 c	79.6 c
T_8 = Sorghum powder soil incorporation: 15 g kg^{-1} soil	77.3 d	76.2 d	75.0 d
T_9 = Sorghum powder soil incorporation: 30 g kg^{-1} soil	72.8 e	71.1 e	70.3 e
SE	0.2321	0.0314	0.2196
LSD 0.05	0.4920	0.0666	0.4656

Root length (cm)

Root length (cm) of test weeds were remarkably (p<0.05) lessened by the extracts and powders of bermudagrass and sorghum in contrast to control treatment (Table 2). Lowest (1.4 cm) root length of *Echinochloa colonum* was documented in sorghum extract @ 30 ml kg^{-1} soil. Extract of sorghum @ 15 ml kg^{-1} soil gave 2nd lowest (1.5 cm) length of roots. For *Echinochloa crusgalli* least (2.7 cm) root length was recorded when extract of sorghum was used @ 30 ml kg^{-1} soil. Lower root length at 2nd rank with statistical equal values of 2.8 cm was noticed in extract of bermudagrass @ 30 ml kg^{-1} soil and sorghum @ 15 ml kg^{-1} soil. Similar trend of allelopathic inhibitory potential with least values was also observed in *Cyperus rotundus* where sorghum extract @ 30 ml kg^{-1} soil resulted in 2.6 cm root length followed by sorghum extract @ 15 ml kg^{-1} soil with 2.7 cm root length. This inhibition in the length of root of could be linked to allelopathic chemicals presence having phytotoxic potential. The allelochemicals are released into the soil rhizosphere during the plant life-cycle or by the incorporation of crop debris, i.e., stubble or stalk into the soil (Jabran, 2017). The biochemical and physiological action mode of phenolic compounds on target plant species includes reduction in root and shoot growth, interference with photosystem-II through electron transport and primary action on ATP production. In addition, this includes the inhibition of chloroplast oxygen evolution, a strong effect on mitochondrial function, alteration of nutrient absorption, chlorophyll pigments, carbon isotope discrimination or water use efficiency (Macias *et al*., 2019).

Table 2. Effect of sorghum and bermudagrass extracts and powder soil incorporation on root length (cm) of rice associated weeds

Treatments	***Echinochloa colonum***	***Echinochloa crusgalli***	***Cyperus rotundus***
T_1 = Untreated (Check)	2.9 a	3.2 a	4.0 a
T_2 = Bermudagrass water extracts: 15 ml kg^{-1} soil	1.9 f	2.9 e	3.1f
T_3 = Bermudagrass water extracts: 30 ml kg^{-1} soil	1.7 g	2.8 f	2.9 g
T_4 = Sorghum water extracts: 15 ml kg^{-1} soil	1.5 h	2.8 f	2.7 h
T_5 = Sorghum water extracts: 30 ml kg^{-1} soil	1.4 i	2.7 g	2.6 i
T_6 = Bermudagrass powder soil incorporation: 15 g kg^{-1} soil	2.6 b	3.1 b	3.8 b
T_7 = Bermudagrass powder soil incorporation: 30 g kg^{-1} soil	2.4 c	3.1 c	3.6 c
T_8 = Sorghum powder soil incorporation: 15 g kg^{-1} soil	2.3 d	3..0 d	3.5 d
T_9 = Sorghum powder soil incorporation: 30 g kg^{-1} soil	2.1 e	3.0 d	3.3 e
SE	0.0319	0.0283	0.0272
LSD 0.05	0.0677	0.0601	0.0577

Shoot length (cm)

The shoot length (cm) of tested weeds was significantly decreased by the application of bermudagrass and sorghum extracts and powders (Table-3) as against control treatment. Lowest (10.4 cm) shoot length of *Echinochloa colonum* was

registered in extract of sorghum @ 30 ml kg^{-1} soil. The respective extracts of sorghum and bermudagrass @ 15 and 30 ml kg^{-1} soil ranked 2nd and 3rd with 11.6 and 12.8 cm shoot length, respectively. As regards *Echinochloa crusgalli*, extract of sorghum @ 30 ml kg^{-1} soil established dominance in phytotoxic influence and conferred statistically lowest (12.0 cm) shoot length. The 2nd and 3rd least (13.6 & 15.3 cm) shoot length was noticed in extract of sorghum @ 15 ml kg^{-1} soil and extract of bermudagrass @ 30 ml kg^{-1} soil. For *Cyperus rotundus*, extract of sorghum @ 30 and 15 ml kg^{-1} soil, and extract of bermudagrass @ 30 ml kg^{-1} soil resulted in lower 8.4, 9.6 and 10.8 cm shoot length, respectively. Water extracts and powders of bermudagrass and sorghum in comparison with control caused significant effects on shoot length. Inhibition in tested weeds shoot length by bermudagrass and sorghum extracts and powders reveals that these botanicals possess allelochemicals. It is noteworthy that allelopathic materials extract surpassed powders in phytotoxic potential. Sorgoleone is the best example of natural herbicide which is secreted as root exudates from sorghum plant (Tibugari *et al*., 2020). At the juvenile stage, sorghum plants secrete significant concentrations of sorgoleone, reaching high concentrations in the root hairs (0.5 mg g^{-1} of root fresh weight). The potential of this allelopathic chemical is high in the suppression and inhibition of weed growth without disturbing the crop species (Besancon *et al*., 2020). The more inhibiting impact of extracts of allelopathic botanicals on growth of weeds may be linked to their solubilized and readily available forms which caused adverse effects on the radicles and slowed down uptake of nutrients and water, chlorophyll contents, and eventually photosynthesis process (Hozayn *et al*., 2011).

Table 3. Effect of sorghum and bermudagrass extracts and powder soil incorporation on shoot length (cm) of rice associated weeds

Treatments	***Echinochloa colonum***	***Echinochloa crusgalli***	***Cyperus rotundus***
T_1 = Untreated (Check)	20.2 a	23.6 a	17.7a
T_2 = Bermudagrass water extracts: 15 ml kg^{-1} soil	14.0 f	16.5 def	12.0 f
T_3 = Bermudagrass water extracts: 30 ml kg^{-1} soil	12.8 g	15.3 efg	10.8 g
T_4 = Sorghum water extracts: 15 ml kg^{-1} soil	11.6 h	13.6 fg	9.6 h
T_5 = Sorghum water extracts: 30 ml kg^{-1} soil	10.4 i	12.0 g	8.4 i
T_6 = Bermudagrass powder soil incorporation: 15 g kg^{-1} soil	18.8 b	22.4 ab	16.6 b
T_7 = Bermudagrass powder soil incorporation: 30 g kg^{-1} soil	17.6 c	20.9 abc	15.6 c
T_8 = Sorghum powder soil incorporation: 15 g kg^{-1} soil	16.4 d	19.6 bcd	14.4 d
T_9 = Sorghum powder soil incorporation: 30 g kg^{-1} soil	15.2 e	17.9 cdf	13.2 e
SE	0.0943	1.6610	0.0299
LSD 0.05	0.1999	3.5211	0.0634

Fresh biomass (g seedling $^{-1}$)

Table-4 shows that extracts and powders of bermudagrass and sorghum exhibited remarkable suppression of fresh biomass of weeds under test. For *Echinochloa colonum*, the minimum (4.9 g seedling^{-1})

biomass was noticed in extract of sorghum @ 30 ml kg^{-1} soil. Extract of sorghum @ 15 ml kg^{-1} soil and extract of bermudagrass @ 15 ml kg^{-1} soil yielded 2nd and 3rd least (5.5 and 6.1 g $seedling^{-1}$) fresh biomass. In case of *Echinochloa crusgalli*, lowest (5.6, 6.5 and 7.4 g $seedling^{-1}$) fresh biomass was recorded under the application of extract of sorghum @ 30 ml kg^{-1} soil, extracts of sorghum @ 15 ml kg^{-1} soil and extract of bermudagrass @ 30 ml kg^{-1} soil, correspondingly. As far as bermudagrass and sorghum allelopathic effects on *Cyperus rotundus* are concerned, highest suppression was noted in extract of sorghum @ 30 and 15 ml kg^{-1} soil, and extract of bermudagrass @ 15 ml kg^{-1} soil having respective lowest (4.0, 4.9 and 5.8 g $seedling^{-1}$) fresh biomass. The inhibition of tested weeds fresh biomass can be associated to compounds with allelopathic properties present in bermudagrass and sorghum extracts and powders. Matos *et al*. (2021) conducted study to investigate the bioherbicidal power of sorghum against seedlings of *Cyperus rotundus* (L.) where four kinds of sorghum extract were applied root extraction in water, root extraction in alcohol, leaf extraction in water and leaf extraction in alcohol under five concentrates of sorghum (0% extract, 20% extract, 40% extract, 80% extract and 100% extract). It was observed from the results that leaf extract of sorghum exhibited substantial effect on growth attributes *of Cyperus rotundus*. Water and nutrients uptake are suppressed by allelopathic chemicals thus reducing photosynthesis and biomass growth (Jafariehyazdi and Javidfar, 2011).

Table 4. Effect of sorghum and bermudagrass extracts and powder soil incorporation on fresh biomass (g $seedling^{-1}$) of rice associated weeds

Treatments	*Echinochloa colonum*	*Echinochloa crusgalli*	*Cyperus rotundus*
T_1 = Untreated (Check)	9.7 a	13.4 a	11.0 a
T_2 = Bermudagrass water extracts: 15 ml kg^{-1} soil	6.7 f	8.3 f	6.7 f
T_3 = Bermudagrass water extracts: 30 ml kg^{-1} soil	6.1 g	7.4 g	5.8 g
T_4 = Sorghum water extracts: 15 ml kg^{-1} soil	5.5 h	6.5 h	4.9 h
T_5 = Sorghum water extracts: 30 ml kg^{-1} soil	4.9 i	5.6 i	4.0 i
T_6 = Bermudagrass powder soil incorporation: 15 g kg^{-1} soil	9.1 b	11.9 b	10.4 b
T_7 = Bermudagrass powder soil incorporation: 30 g kg^{-1} soil	8.5 c	11.0 c	9.5 c
T_8 = Sorghum powder soil incorporation: 15 g kg^{-1} soil	7.9 d	10.1 d	8.6 d
T_9 = Sorghum powder soil incorporation: 30 g kg^{-1} soil	7.3 e	9.2 e	7.7 e
SE	0.0157	0.0956	0.0848
LSD 0.05	0.0333	0.2026	0.1798

Dry biomass (g $seedling^{-1}$)

The dry biomass of weeds under test was affected markedly (Table-5) by the application of bermudagrass and sorghum allelopathic material as compared to check treatment. In case of *Echinochloa colonum*, the least (1.8 g $seedling^{-1}$) dry biomass was noticed in sorghum water extracts @ 30 ml kg^{-1} soil followed by extract of sorghum @ 15 ml kg^{-1} soil, and extract of bermudagrass @ 30 ml kg^{-1} soil (1.9 and 2.1 g $seedling^{-1}$), respectively. As

regards *Echinochloa crusgalli*, the application of sorghum water extract @ 30 ml kg^{-1} soil resulted in least (2.4 g $seedling^{-1}$) dry biomass whereas sorghum water extract @ 15 ml kg^{-1} soil and bermudagrass water extract @ 15 ml kg^{-1} soil ranked 2nd and 3rd in allelopathic inhibitory efficacy having 2.7 and 3.0 g dry biomass $seedling^{-1}$. As far as *Cyperus rotundus* (L.) is concerned, greatest reduction (2.4 g $seedling^{-1}$) in dry biomass was detected in sorghum water extracts @ 30 ml kg^{-1} soil. However, extract of sorghum @ 15 ml kg^{-1} soil and bermudagrass water extract @ 15 ml kg^{-1} soil gave respective 2.6 and 2.8 g dry biomass $seedling^{-1}$. The diminishing of targeted weeds dry biomass could be connected to length of seedling as affected by chemicals allelopathic nature present in bermudagrass and sorghum extracts and powders. Water and nutrients uptake is suppressed by allelopathic chemicals thus, reducing photosynthesis and biomass growth (Nazir et al., 2022). It is envisaged from the results that effects of allelopathic action of bermudagrass and sorghum were specific to forms and plant parts. Extracts of both bermudagrass and sorghum showed higher allelopathic adverse effects against powder. The water extract of bermudagrass and sorghum significantly decreased the dry biomasses of the weeds. The application of water extracts of sorghum demonstrated remarkable inhibition of weeds (Shi *et al*., 2021). The laboratory experiments were performed to evaluate the allelopathic potential of water extracts on weeds and crops prepared from different parts of sorghum. The results indicated that phytotoxic action of sorghum was source, concentration and species specific. The water extract prepared from roots, leaves and stems of sorghum decreased the development of *Echinochloa colonum* seedlings significantly. It was found that extract prepared from stem provoked the outstanding suppressive on test weed (Kim *et al*., 2012). Dry biomass of weeds was significantly suppressed by the compounds of allelopathic nature present in extracts of leaves of allelopathic plants (Khan *et al*., 2015).

Table 5. Effect of sorghum and bermudagrass extracts and powder soil incorporation on dry biomass (g $seedling^{-1}$) of rice associated weeds

Treatments	***Echinochloa colonum***	***Echinochloa crusgalli***	***Cyperus rotundus***
T_1 = Untreated (Check)	3.0 a	4.7 a	4.1 a
T_2 = Bermudagrass water extracts: 15 ml kg^{-1} soil	2.2 f	3.3 f	3.0 f
T_3 = Bermudagrass water extracts: 30 ml kg^{-1} soil	2.1 g	3.0 g	2.8 g
T_4 = Sorghum water extracts: 15 ml kg^{-1} soil	1.9 h	2.7 h	2.6 h
T_5 = Sorghum water extracts: 30 ml kg^{-1} soil	1.8 i	2.4 i	2.4 i
T_6 = Bermudagrass powder soil incorporation: 15 g kg^{-1} soil	2.8 b	4.4 b	3.8 b
T_7 = Bermudagrass powder soil incorporation: 30 g kg^{-1} soil	2.7 c	4.2 c	3.6 c
T_8 = Sorghum powder soil incorporation: 15 g kg^{-1} soil	2.5 d	3.9 d	3.4 d
T_9 = Sorghum powder soil incorporation: 30 g kg^{-1} soil	2.4 e	3.6 e	3.2 e
SE	0.0248	0.0215	0.0333
LSD 0.05	0.0527	0.0456	0.0707

CONCLUSION

It is concluded from the outcomes of laboratory based study that different levels of water extracts and powders of bermudagrass and sorghum exhibited marked allelopathic influence on germination and subsequent growth of weeds associated with rice crop as compared to untreated (control) treatment. Sorghum material caused the highest allelopathic influence in contrast to bermudagrass. Extracts surpassed powders in allelopathic effectiveness. Hence, it is suggested that allelopathic properties of bermudagrass and sorghum could be utilized for effective weed management in rice.

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