PLANTA DANINHA

SBCPD
SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Allelopathic Influence of Sorghum Aqueous Extracts and Sorghum Powder on Germination Indices and Seedling Vigor of Hybrid Corn and Jungle Rice

Influência Alelópática de Extratos Aquosos de Sorgo em Pó sobre Níveis de Germinação e Vigor de Plântuulas de Milho Híbrido e Arroz de Selva

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ABSTRACT - Allelopathy has become a paramount tool for controlling weeds in crop plants without deteriorating the environment. Allelopathic effects of sorghum aqueous extracts and sorghum powder on a single cross maize (*Zea mays* L.) hybrid "HC-8080" and a summer weed, jungle rice (*Echinochloa colona* L.) were assessed in the research laboratory of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK, Pakistan. The treatments included: T1: control (untreated check), T2: sorghum aqueous extract at a rate of 5 mL kg^{-1} soil, T3: sorghum aqueous extract at a rate of 10 mL kg^{-1} soil, T4: sorghum aqueous extract at a rate of 15 mL kg^{-1} soil, T5: sorghum powder at a rate of 5 g kg^{-1} soil, T6: sorghum powder at a rate of 10 g kg^{-1} soil and T7: sorghum powder at a rate of 15 g kg^{-1} soil. The results unveiled that sorghum aqueous extract at a rate of 15 mL kg^{-1} soil was the most deleterious treatment which reduced the germination percentage (GP) in maize and *E. colona* by 23.57% and 47.03%, germination index (GI) by 22.30% and 42.14%, root length by 32.25% and 62.54% and shoot length by 23.22% and 62.76%, respectively over control. Similarly, 15 g kg^{-1} soil sorghum powder reduced the same parameters respectively by 18.85% and 41.09%, 15% and 33.53%, 9.3% and 54.69% and 15.88% and 45.34% in maize and *E. colona,* respectively and stood better than other powder treatments. Therefore it is concluded that sorghum extracts and powder can both be used to control weeds efficiently but their deleterious effect on the corresponding crop should also be an important consideration.

Keywords: sorghum allelopathy, germination, growth, maize.

*RESUMO - A alelopatia tornou-se uma ferramenta primordial para o controle de plantas daninhas em plantas cultivadas sem deteriorar o meio ambiente. Os efeitos alelopáticos de extratos aquosos de sorgo e sorgo em pó em um único híbrido de milho (**Zea mays** L.), híbrido HC-8080, e um arbusto de verão (**Echinochloa colona** L.) foram avaliados no laboratório de pesquisa da Agronomia, Faculdade de Agricultura, Universidade Gomal, Dera Ismail Khan, KPK, Paquistão. Os tratamentos foram: T1: controle (testemunha não tratada); T2: extrato aquoso de sorgo com taxa de 5 mL kg^{-1} de solo; T3: extrato aquoso de sorgo com taxa de 10 mL kg^{-1} solo; T4: extrato aquoso de sorgo a com taxa de 15 mL kg^{-1} de solo; T5: sorgo em pó a com taxa de 5 g kg^{-1} de solo; T6: sorgo em pó a com taxa de 10 g kg^{-1} de solo; e T7: sorgo em pó a com taxa de 15 g kg^{-1} de solo. Os resultados revelaram que o extrato aquoso de sorgo com 15 mL kg^{-1} de solo foi o tratamento mais*

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Received: February 27, 2018
Approved: June 4, 2018

Planta Daninha 2020; v38:e020192192

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Doi: 10.1590/S0100-83582020380100005

deletério, tendo reduzido a porcentagem de germinação (GP) em milho e ***E. colona*** *em 23,57% e 47,03%, o índice de germinação (GI) em 22,30 % e 42,14%, o comprimento de raiz em 32,25% e 62,54% e o comprimento de parte aérea em 23,22% e 62,76%, respectivamente, em relação ao controle. Da mesma forma, 15 g kg*$^{-1}$ *de sorgo em pó reduziram os mesmos parâmetros, em 18,85% e 41,09%, 15% e 33,53%, 9,3% e 54,69% e 15,88% e 45,34% em milho e* ***E. colona****, respectivamente, em relação aos outros tratamentos em pó. Portanto, conclui-se que extratos de sorgo em pó podem ser usados para controlar plantas daninhas eficientemente, porém seu efeito deletério na cultura correspondente também deve ser uma consideração importante.*

Palavras-chave: alelopatia do sorgo, germinação, crescimento, milho.

INTRODUCTION

Weeds, if not timely managed, pose a looming threat to crop productivity deteriorating the quality and quantity of produce and drastically reducing the income of the farmers (Jabran et al., 2010). These weeds interfere with the normal life cycle of crops by competing with them for the available resources and also exhibit allelopathic properties which add more to their negative influence on the crop plants (Hozayn et al., 2011). Weeds, being vigorous in nature, usually germinate and grow faster and consume the available resources earlier than the associated crop, thus the crop plants get smothered by the weeds (Bhatt and Tewari, 2006; Cheema et al., 2010).

Echinochloa species have been included among the most noxious weed species of the world (Bajwa et al., 2015), wherein, *Echinochloa colona* L. (Link) has been reported to be the most dangerous summer grassweed found globally in many summer crops, particularly rice and maize (Rao et al., 2007). It is distributed worldwide as a noxious weed and is abundantly found in Africa, Asia and Australia (Bajwa et al., 2016). The persistent nature and high survival rate of this weed specie under variegated photoperiodic conditions is associated with its higher rate of seed production, shorter dormancy period, quick emergence and fast vegetative and reproductive growth patterns (Chauhan and Johnson, 2010). In spite of the enormous economic importance of this weed, negligible work has been done for its efficient control so far.

In general, different methods have been adopted over the years for efficient control of weeds. Among these methods, chemical weed control method which involves the use of herbicides has been frequently adopted. Although, weeds can be efficiently controlled through herbicide application, but these chemicals may impose deleterious effects on the above and below ground environment (Cheema et al., 2010). On the other hand, frequent use of such herbicides has developed resistance in weed species which were earlier susceptible to them (Cheema et al., 2002). *Echinochloa colona* is also one such specie which has also developed resistance over time to several herbicides including, atrazine, glyphosate, clefoxidym, bispyribac-sodium, fenoxaprop-p-ethyl, propanil, triazine, ametryn, cyhalofop-butyl and metribuzin, making itself a more cumbersome weed for crops (Bajwa et al., 2016).

Under such a situation, endeavors should be made to develop latest techniques for weed control which are long lasting and eco-friendly as well. Allelopathy is one such phenomenon which can provide efficient and eco-friendly weed control. Several crop plants produce allelochemicals which are released in to the soil and reduce germination and growth of the plants in the vicinity (Cheema et al., 2003). It is well known that sorghum (*Sorghum bicolor* L.) is an allelopathic crop which influences weeds and other crops growth (Alsaadawi et al., 2005). It possesses certain cyanogenic glucosides which suppress plant growth (Cheema et al., 2007). Decomposed shoots of sorghum residues release phenolic compounds which render inhibitory influence on plants (Sene et al., 2001).

Thus, this study was aimed at examining the allelopathic potential of sorghum aqueous extracts and sorghum powder on maize and *Echinochloa colona* seeds and to figure out the comparative degree of allelopathic impact of sorghum extract and powder on maize and *Echinochloa colona* seeds via different germination and growth indices.

MATERIALS AND METHODS

A laboratory experiment was conducted at the Agronomy research laboratory, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan during 2017, in order to assess the allelopathic influence of sorghum aqueous leachates and sorghum powder on the germination and seedling vigor of a maize hybrid (HC-8080) and an associated weed; jungle rice (*Echinochloa colona*). Completely randomized design (CRD) comprising four replications was followed for executing the experiment in pots having 30 cm x 15 cm x 15 cm (H x L x W) size.

All the pots were filled with 5 kg soil, having silty clay loam texture (45% silt, 35% clay and 20% sand), obtained from student farms of the university. 50 seeds, each of maize and weed were sown in each pot separately and treatments were applied as; T_1: Control (tap water treatment), T_2: sorghum aqueous extract at a rate of 5 mL kg^{-1} soil, T3: sorghum aqueous extract at a rate of 10 mL kg^{-1} soil, T4: sorghum aqueous extract at a rate of 15 mL kg^{-1} soil, T5: sorghum powder at a rate of 5 g kg^{-1} soil, T6: sorghum powder at a rate of 10 g kg^{-1} soil, T7: sorghum powder at a rate of 15 g kg^{-1} soil.

Sorghum herbage was also accumulated from the student's fields. The herbage was dried under the sun and then was chopped with a chopper in to small pieces which were then ground to make powder with the help of a grinder (Kandhro et al., 2016). To prepare the extract treatments, the powder was soaked in distilled water in the ratio 1:10 (w/v) for 48 hours and the required concentrations were obtained. With the help of a muslin cloth the extracts were filtered from the powder. The powder was thoroughly mixed with the soil contained in each pot, except control, before sowing the maize and jungle rice seeds, while in case of extracts, sowing was done and then extract treatments were applied on the soil. All the experimental pots were kept moist according to the requirement.

Data were collected on daily basis for 10 days and then the average results were calculated and recorded. For seedling growth parameters, the data were taken after 30 days after sowing (DAS) and means were worked out for each treatment.

Germination percentage (GP)

GP was calculated by counting the total number of seeds germinated in each pot and then dividing the value with total number of seeds sown. The obtained result was then multiplied with 100.

Mean germination time (MGT)

MGT was calculated by the formula (Orchard, 1997):

$$MGT = \sum fx / \sum f$$

(where f is the number of seeds germinated on day *x*)

Germination index (GI)

GI was worked out with the help of a formula as under:

$$GI = (10\ X\ n1) + (9\ X\ n2) + \cdots (1\ X\ n10)$$ (Arnold et al., 1991)

*n*1, *n*2——*n*10 where "n" represents the number of seeds germinated on 1st, 2nd and so on up to the 10th day.

Speed of germination

It was obtained by the formula given by (Czabator, 1962):

$$Speed\ of\ germination = \frac{n1}{d1} + \frac{n2}{d2} + \cdots + \frac{nx}{dx}$$

("*n*" represents the number of seeds germinated while "*d*" the number of days)

Coefficient of velocity of germination (CVG)

It was calculated by the formula presented by (Jones and Sanders, 1987):

$$CVG = \frac{n1+n2+\cdots nx}{n1d1+n2d2+\cdots nxdx}$$

where, "*n*" is the number of seeds germinated on days "*d*"

Peak value (PV)

It was calculated by the formula suggested by (Czabator, 1962) as:

$$PV = \frac{Highest\ number\ of\ seeds\ germinated}{Number\ of\ days}$$

Root length (cm)

Both the maize and jungle rice seedlings were uprooted after 30 DAS and length of roots were measured with the help of a measuring tape for each treatment and then averaged out.

Shoot length (cm)

Similar procedure was adopted for measuring shoot length as was adopted for root length.

RESULTS AND DISCUSSION

Germination percentage (GP)

A significant (P≤5) reduction in germination percentage of both maize and *E. colona* (jungle rice) seeds was noticed with the application of sorghum aqueous extract and sorghum powder treatments as depicted in Table 1. However, germinability of maize was not affected at the lowest rates (5 mL kg^{-1} soil and 5 g kg^{-1} soil, respectively) of sorghum extract and powder but the same treatments lowered the GP of *E. colona* by 10.82% and 8.11%, respectively over control. Overall, the allelopathic effect was more pronounced on *E. colona* seeds than the maize kernels. Lowest germination (73% and 49%) was recorded in maize and *E. colona* seeds respectively with highest rate (15 mL kg^{-1} soil) of sorgaab (sorghum aqueous extract), which showed a respective reduction of 23.57% and 47.03%, as presented in the parenthesis (Table 1), over the untreated check. Nevertheless, sorgaab at a rate of 10 mL kg^{-1} soil and sorghum powder at a rate of 15 g kg^{-1} soil reduced the GP (41.63 and 41.09%, respectively) of jungle rice as compared to control and had statistically similar results with the highest dose (15 mL kg^{-1} soil) of sorgaab. Sorgaab at a rate of 10 mL kg^{-1} soil, on the other hand caused 17.18% lesser seed germination in maize than control restricting the GP to 78.5%. Sorghum powder also had a noticeable impact on GP of both the seed types, wherein maximum reduction in maize germination (18.85%) was noticed with highest dose (15 g kg^{-1} soil) of powder. This was followed by 10 g kg^{-1} soil sorghum powder which lowered the GP in maize by 12.57% and jungle rice by 31.36% than control. These results unveiled that sorghum exhibits strong allelochemicals which inhibited germination both in crop and weed seeds but the impact was more prominent in the latter. Furthermore, sorghum aqueous extracts caused more inhibition in germination than powder on both the maize and *E. colona* seeds. Lowest concentrations did not influence the germination percentage because allelochemicals are concentration dependent as Cheema and Khaliq (2001) stated that sorghum allelochemicals are species specific and concentration dependent in their effect. These results are in line with the findings of (Randhawa et al., 2002) who suggested that sorghum contains certain allelochemicals which can inhibit the germination of several weeds. Mubeen et al. (2012) reported significant reduction in germination percentage of rice and associated weeds with the application of sorghum and sunflower water extracts.

Table 1 **-** Germination percentage in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Germination percentage		
Treatment	Maize	*E. colona*
Control (untreated check)	95.504 a	92.500 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	92.000 a (-3.67)	82.500 b (-10.82)
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	78.500 c (-17.18)	54.000 d (-41.63)
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	73.002 d (-23.57)	49.002 d (-47.03)
Sorghum powder at a rate of 5 g ka^{-1} soil	94.005 a (-1.58)	85.000 b (-8.11)
Sorghum powder at a rate of 10 g ka^{-1} soil	83.509 b (-12.57)	63.505 c (-31.36)
Sorghum powder at a rate of 15 g ka^{-1} soil	77.500 cd (-18.85)	54.502 d (-41.09)
$LSD_{0.05}$	4.534	5.637

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

Germination index (GI)

Germination index represents both the seed germination and germination speed. Its value is higher for the seeds which germinate earlier than the ones which germinate latter. Germination index in maize and *E. colona*, as indicated in Table 2, was significantly decreased by all the treatments except sorgaab at a rate of 5 mL kg^{-1} soil and sorghum powder at a rate of 5 g kg^{-1} soil. Maximum diminution of 22.30% and 42.14% (252.75 and 154.50 GI), in comparison with control, had respectively occurred in maize and *E. colona* with 15 mL kg^{-1} soil sorgaab which, in case of maize, was statistically at par with sorgaab application at a rate of 10 mL kg^{-1} soil showing a reduction of 18.30% (265.75) GI over control. The said treatment (sorgaab at a rate of 10 mL kg^{-1} soil) also lowered the GI in *E. colona* by 33.24% (178.25) than the untreated check and was found statistically non-significant with GI of 177.50 (33.53% reduction over control) recorded for sorghum powder at a rate of 15 g kg^{-1} soil. Sorghum powder at a rate of 15 g kg^{-1} soil and at a rate of 10 g kg^{-1} soil respectively lessened the GI by 15% (276.50) and 11.07% (289.25) in maize, while the latter treatment also imposed reducing effect on the GI of *E. colona* registering GI of 205.25 (23.13% less over control). Sorghum, being allelopathic in nature, had the tendency to negatively affect the germinability of weed and crop seeds under study. Mubeen et al. (2012) reported that although both the crop and weed seeds were significantly altered, however the germination index of rice was less affected by sorghum and sunflower aqueous extracts but that of weeds (*T. portulacastrum*, *D. egyptium* and *E. indica*) was influenced more. Their results are in accordance with the findings of the current study.

Mean germination time (MGT)

Table 3 showed the data for mean germination time of maize and *E. colona* under the influence of sorghum water extracts and sorghum powder treatments. There was no significant impact of

Table 2 **-** Germination index in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Germination index		
Treatment	Maize	*E. colona*
Control (untreated check)	325.253 a	267.000 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	321.250 ab (-1.23)	257.500 a (-3.56)
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	265.751 c (-18.30)	178.257 bc (-33.24)
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	252.753 c (-22.30)	154.506 c (-42.14)
Sorghum powder at a rate of 5 g kg^{-1} soil	324.750 a (-0.6)	260.753 a (-2.35)
Sorghum powder at a rate of 10 g kg^{-1} soil	289.252 abc (-11.07)	205.253 b (-23.13)
Sorghum powder at a rate of 15 g kg^{-1} soil	276.505 bc (-15.0)	177.500 bc (-33.53)
$LSD_{0.05}$	46.132	41.148

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

Table 3 **-** Mean germination time (days) in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Mean germination time		
Treatment	Maize	*E. colona*
Control (untreated check)	4.000[NS]	4.835 c
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	3.902	5.162 c
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	4.055	6.372 b
Sorghum aqueous extract at a rate of 15ml kg^{-1} soil	4.007	7.377 a
Sorghum powder at a rate of 5 g kg^{-1} soil	3.750	4.582 c
Sorghum powder at a rate of 10 g kg^{-1} soil	3.990	5.277 c
Sorghum powder at a rate of 15 g kg^{-1} soil	4.032	6.347 b
$LSD_{0.05}$	-	0.913

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

any of the treatments on the MGT of maize kernels, however, weed seeds were significantly affected by them. Maximum time for germination (7.377 days) was taken by weed seeds treated with 15 mL kg^{-1} soil of sorghum extracts. Sorghum aqueous extracts at a rate of 10 mL kg^{-1} soil and sorghum powder at a rate of 15 g kg^{-1} soil delayed the mean germination time of jungle rice by 6.372 and 6.347 days as compared to control (4.835 days). Whereas, sorghum aqueous extract at a rate of 5 mL kg^{-1} soil, sorghum powder at a rate of 5 g kg^{-1} soil and at a rate of 10 g kg^{-1} soil did not have any significant effect on MGT of weed showing statistically similar results (5.162, 4.582 and 5.277 days, respectively) with that of control as shown in Table 3. The differences in mean values for the mean germination time of *E. colona* might be due to the suppressing effect of sorghum aqueous extracts and sorghum powder, while the non-significant impact on the maize seeds might be attributed to the rapid metabolizing ability of the crop seeds converting the allelochemicals in to inactive forms. These results are corroborated by Mubeen et al. (2012) indicated that germination index of three weed species differed significantly due to the application of sorghum and sunflower water extracts, wherein, sorghum aqueous leachates were found more alleopathic than sunflower. Similarly Kandhro et al. (2015) revealed that germination indices of some summer weeds were found to be reduced under the suppressing influence of sorghum water extracts and their findings are almost in agreement with our findings.

Germination speed (GP)

Germination speed in both maize and *E. colona* was significantly reduced by all the applied treatments except sorghum aqueous extract at a rate of 5 mL kg^{-1} soil and sorghum powder at a rate of 5 g kg^{-1} soil (Table 4). Maximum reduction in germination speed (11.025 and 7.432) of maize and *E. colona*, respectively was noticed with the application of highest dose of sorgaab (15 mL kg^{-1} soil). Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil and sorghum powder at a

Table 4 **-** Germination speed in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Germination speed		
Treatment	Maize	*E. colona*
Control (untreated check)	17.610 a	15.218 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	17.105 ab	14.278 a
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	13.713 c	9.020 c
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	11.025 d	7.432 d
Sorghum powder at a rate of 5 g kg^{-1} soil	17.328 ab	14.648 a
Sorghum powder at a rate of 10 g kg^{-1} soil	15.773 b	11.375 b
Sorghum powder at a rate of 15 g kg^{-1} soil	13.665 c	9.890 bc
$LSD_{0.05}$	1.731	1.575

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

rate of 15 g kg^{-1} soil gave statistically similar results (P≤5) in maize, reducing the germination speed to 13.713 and 13.665, respectively over control (17.610). Whereas, sorghum powder at a rate of 10 g kg^{-1} soil caused a reduction of 15.773 as compared to the untreated treatment. Similarly, after highest dose of sorgaab, GP in *E. colona* was maximally reduced (9.020) by sorghum aqueous extract at a rate of 10 mL kg^{-1} soil. This was followed by sorghum powder at a rate of 15 g kg^{-1} soil and sorghum powder at a rate of 10 g kg^{-1} soil which reduced the GP in *E. colona* to 9.890 and 11.375, respectively as compared to the untreated check. Maize seeds did not get influenced by the allelopathic leachates and powder of sorghum, however weed seeds under study were negatively affected by the treatments. Kandhro et al. (2016) applied sorghum and sunflower water extracts and powder treatments on cotton and some weeds and revealed the presence of water soluble allelopathic compounds in the above and below ground parts of both the test crops. Their results indicated a noticeable level of reduction in the germination indices and seedling growth of crop and the weeds which are in cognizance with the present results.

Coefficient of velocity of germination (CVG)

Coefficient of velocity of germination (CVG) is indicative of the rapidity with which the seeds germinate. The more the seeds germinate in lesser time, the more the CVG will be. The CVG in maize remained unaffected by the treatments applied (Table 5), however, sorghum aqueous extract at a rate of 15 mL kg^{-1} soil was the only treatment which reduced the CVG (16.538) as compared to control (24.500). On the other, CVG in *E. colona* was non-significantly affected (P≤5) where least doses of sorgaab and sorghum powder i.e. 5 mL kg^{-1} soil and 5 g kg^{-1} soil, respectively, were applied. Nevertheless, maximum reduction (9.850) in the said treatment was recorded with sorghum aqueous extract at a rate of 15 mL kg^{-1} soil which was followed by statistically at par results noted against sorghum aqueous extract at a rate of 10 mL kg^{-1} soil and sorghum powder at a rate of 15 g kg^{-1} soil restricting the CVG value to 12.650 and 14.460, in the order given. Least effect, on the other hand, was observed with sorghum powder at a rate of 10 g kg^{-1} soil with a CVG of 16.858. Maize showed considerable resistance to all the treatments in terms of CVG but was influenced only by the highest dose of sorghum water extracts while, *E. colona* in contrast showed susceptibility to almost all the applied treatments. Khan et al. (2012) applied the aqueous leachates of sorghum, sunflower, brassica and rice for weed control in wheat crop and indicated the presence of alleochemicals in these crops which can influence the germination, growth and development of weeds associated with it.

Table 5 **-** Coefficient of velocity of germination in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Coefficient of velocity of germination		
Treatment	Maize	*E. colona*
Control (untreated check)	24.500 a	24.110 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	23.518 a	23.490 a
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	19.748 ab	12.650 c
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	16.538 b	9.850 d
Sorghum powder at a rate of 5 g kg^{-1} soil	23.833 a	22.715 a
Sorghum powder at a rate of 10 g kg^{-1} soil	21.808 ab	16.858 b
Sorghum powder at a rate of 15 g kg^{-1} soil	19.125 ab	14.460 c
$LSD_{0.05}$	6.310	2.184

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

Peak value

Peak value was not affected significantly (P≤5) in maize by sorghum aqueous extracts and sorghum powder treatments as depicted in Table 6. In case of *E. colona* seeds, the peak value was only influenced significantly by sorghum aqueous extract at a rate of 10 mL kg^{-1} soil and sorghum aqueous extract at a rate of 15 mL kg^{-1} soil reducing the peak value to 2.940 and 3.197

Table 6 **-** Peak value in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Peak Value		
Treatment	Maize	*E. colona*
Control (untreated check)	7.172^{NS}	5.502 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	7.047	5.402 a
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	6.740	3.197 b
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	6.727	2.940 b
Sorghum powder at a rate of 5 g kg^{-1} soil	7.047	5.557 a
Sorghum powder at a rate of 10 g kg^{-1} soil	6.707	4.342 ab
Sorghum powder at a rate of 15 g kg^{-1} soil	6.955	3.650 ab
$LSD_{0.05}$	-	1.963

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

in comparison with control (5.502). Whereas, the rest of the treatments had a non-significant effect on it. Arif et al. (2015) unveiled the presence of certain allelochemicals in water extracts of sorghum such as; protocateuic acid, p-hydroxybenzoic acid, ferulic acid, benzoic acid, gallic acid, syringic acid, m-coumaric acid, caffeic acids, vanillic acid, pcoumaric acid, dhurrin, sorgoleone and p-hydroxybenzaldehyde which cause inhibition in germination process as well as the subsequent growth stages of the weed species.

Root length (cm)

Data for root length (cm) of maize and *E. colona* are presented in Table 7 which revealed significant (P≤5) influence of sorghum extracts and sorghum powder on the parameter. However, lowest rates of both the treatments did not show any significant effect on root length of the crop as well as the weed. In maize, root length was maximally reduced (7.875 cm) where sorghum aqueous extract at a rate of 15 mL kg^{-1} soil was applied. Next in line were sorghum aqueous extract at a rate of 10 mL kg^{-1} and sorghum powder at a rate of 15 g kg^{-1} soil treatments which remained statistically at par restricting the root length to 9.250 cm and 9.300 cm, respectively. While, sorghum powder at a rate of 10 g kg^{-1} soil showed the least reduction of 10.075 cm in root length of maize. In *E. colona*, on the other hand, sorghum aqueous extract at a rate of 10 mL kg^{-1} soil, sorghum aqueous extract at a rate of 15 mL kg^{-1} soil, sorghum powder at a rate of 10 g kg^{-1} soil and sorghum powder at a rate of 15 g kg^{-1} soil all gave statistically at par results for root length (3.650, 3.100, 4.125 and 3.750 cm, respectively). The percent reductions are given in the parenthesis (Table 7). The reduction in the root length of maize and *E. colona* as vivid from the results might have been caused by the allelopathic compounds present in sorghum. Our results are in agreement with that of Sadegi et al. (2010) who reported inhibition in germination, chlorophyll content and root and shoot length with the application of sunflower water extracts.

Table 7 **-** Root length (cm) in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Root length (cm)		
Treatment	Maize	*E. colona*
Control (untreated check)	11.615 a	8.275 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	11.050 ab (-4.87)	7.450 ab (-9.97)
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	9.250 c (-20.37)	3.650 c (-55.09)
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	7.875 d (-32.25)	3.100 c (-62.54)
Sorghum powder at a rate of 5 g kg^{-1} soil	11.500 a (-1.00)	7.600 ab (-8.16)
Sorghum powder at a rate of 10 g kg^{-1} soil	10.075 bc (-13.31)	4.125 c (-50.16)
Sorghum powder at a rate of 15 g kg^{-1} soil	9.300 c (-19.94)	3.750 c (-54.69)
$LSD_{0.05}$	1.322	1.198

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

Shoot length (cm)

Shoot length (cm) in maize and *E. colona*, as given in Table 8, was significantly (P≤5) reduced by the studied treatments. However, shoot length in maize remained unaffected against sorghum aqueous extract at a rate of 5 mL kg^{-1} soil and sorghum powder at a rate of 5 g and 10 g kg^{-1} soil treatments. Moreover, sorghum powder at a rate of 5 g kg^{-1} soil was found ineffective in case of *E. colona* as well. Maximum reduction in shoot length of maize (23.22%) and *E. colona* (62.76%) was recorded with the application of sorghum aqueous extract at a rate of 15 mL kg^{-1} soil. Nevertheless, in maize, sorghum powder at a rate of 15 g kg^{-1} soil ranked second in reducing shoot length (15.88%). Whereas, rest of the treatments i.e. sorghum aqueous extract at a rate of 5 mL kg^{-1} soil, sorghum powder at a rate of 5 g and 10 g kg^{-1} soil depicted statistically non-significant results with each other and reduced the shoot length by 6.24%, 4.41% and 10.55%, respectively. The shoot length in *E. colona* was reduced by 54.33% with sorghum aqueous extract at a rate of 10 mL kg^{-1} soil which stood second in inhibitory efficacy after the full dose (15 mL kg^{-1} soil). Next to this were the treatments of sorghum powder at a rate of 15 g and 10 g kg^{-1} soil lessening the shoot length by 45.34% and 33.23%, respectively. While significantly the least reduction (10.14%) was recorded with 5 mL kg^{-1} soil sorghum aqueous extract. The extract and powder treatments both showed inhibitory influence on shoot length which was more prominent in weed than the crop. This diminution may be because of the presence of certain phytotoxic chemicals present in the aqueous leachates and residues of sorghum plant. The results are in accordance with Peng et al. (2004) who reported that incorporation of sorghum powder in the soil and spraying aqueous extracts prepared from different plant parts demonstrated significant reduction in weed growth.

Table 8 **-** Shoot length (cm) in maize and *E. colona* as affected by sorghum aqueous extracts and sorghum powder under laboratory conditions

Shoot length (cm)		
Treatment	Maize	*E. colona*
Control (untreated check)	30.050 a	22.700 a
Sorghum aqueous extract at a rate of 5 mL kg^{-1} soil	28.175 ab (-6.24)	20.400 b (-10.14)
Sorghum aqueous extract at a rate of 10 mL kg^{-1} soil	26.125 bc (-13.07)	10.368 de (-54.33)
Sorghum aqueous extract at a rate of 15 mL kg^{-1} soil	23.075 c (-23.22)	8.455 e (-62.76)
Sorghum powder at a rate of 5 g kg^{-1} soil	28.725 ab (-4.41)	21.230 ab (-6.48)
Sorghum powder at a rate of 10 g kg^{-1} soil	26.880 ab (-10.55)	15.158 c (-33.23)
Sorghum powder at a rate of 15 g kg^{-1} soil	25.280 bc (-15.88)	12.410 d (-45.34)
$LSD_{0.05}$	3.623	2.081

Similar letter(s) adjoining the means in a column are significant at (P≤5) probability level.

It is concluded from the outcome of this laboratory experiment that sorghum aqueous extracts as well as sorghum powder may be an efficient source of controlling different weeds in maize crop without affecting the crop itself to a greater extent. Furthermore, the study revealed that sorghum water extract was more efficient in reducing the growth and development of weed population than incorporation of sorghum powder in the soil. However, both the treatments did significantly affect the germination process and subsequent growth of weeds and the effect was more convincing with the increase in concentration of the treatments. Therefore, it has been proved from the study that these treatments can be utilized as economical, ecofriendly and efficacious way of controlling weeds in maize.

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