



Original Research

Herbicidal activity of allelopathic extracts of sorghum and some herbicides on wheat and accompanied weeds

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ABSTRACT

The aim of the present work is to evaluate the herbicidal activity allelopathic extracts of sorghum plants (*Sorghum bicolor* L.) on wheat and accompanied weeds namely wild oat and canary grass under local conditions in Egypt. The biocidal activity of the aqueous and methanolic extracts of sorghum was compared with two of the most common herbicides used on wheat i.e. diclofop-methyl and clodinafop-propargyl. Application of the tested materials was carried out by using three concentrations of sorghum extracts (5, 10 and 20%) and the recommended dose of each diclofop-methyl (750 ml/fed) and clodinafop-propargyl (140 gm/fed) under laboratory, green house and semi field conditions. The herbicidal and phytotoxic effects of both biochemical agents and conventional herbicides were carried out by measuring germination percentage, seedling shoots and root length, dry weight, chlorophyll content, plant height, plant numbers, spike length and spike weight of the treated wheat. The obtained results indicated that there is no adverse effect of the tested extracts against the measured parameters of productivity and yield of wheat. At the same time promising herbicidal activity of aqueous and methanolic extracts of sorghum was revealed against wild oat and canary grass in particular with aqueous extract of sorghum at concentration of 20%.

Introduction

Weeds represent the most serious problem that reduces the yield of wheat in Egyptian fields. The most sever weeds in wheat fields are *Avena fatual* L (wild oat) and *Phalaris minor* (canary grass) (El-Metwally and El-Rokiek, 2007). Although effective chemical weed control methods are available, nonetheless, continuous use of the same type of herbicide also leads to the development of herbicide-resistant weed bio-types (Bhowmik and Inderjit, 2003). Several reports indicated the resistance of wild oat and canary grass to clodinafop-propargyl, diclofop-methyl, fenoxaprop-p-ethyl, isoproturon, fluazifop-p-butyl, haloxyfop-methyl, sethoxydim and tralkoxydim in various

countries across the globe (Heap, 2007). In addition, herbicides pollute the soil, water and aerial environments and may enhance the disease risks (Ronald, 2000). Sorghum (*Sorghum bicolor* L. Moench) is well-recognized as an allelopathic plant. *Sorghum halepense* is a summer, large, perennial grass which could propagate by its own seeds or rhizomes. Its great allelopathic substances (Asgharipour and Armin, 2010). Mature sorghum produces a large number of water-soluble allelochemicals (Gill et al. 1993). Ahmad et al. (1991) concluded that sorghum is highly allelopathic and its residue could be effectively used to manage some of the important weeds in irrigated wheat crop without affecting crop in semi-arid environment. Water extract of matured sorghum plants was used by Cheema and Khaliq (2000) who reported that water extract reduced weed biomass by 35-40% and increased wheat yield by 10-21%. This study was conducted in order to evaluate the allelopathic potential of sorghum aqueous and methanolic extracts on seed germination characteristics, seedling and plant growth of wheat and herbicidal activity on accompanied weeds wild oats and, canary grass.

Material and Methods

This research was carried out under laboratory, semi field and greenhouse conditions at the agronomic research area, faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Preparation of tested plant extracts.

Sorghum Aqueous Extracts (SAE): the sorghum plants were harvested at maturity stage after the removal of their heads. The plant materials were dried under shade for a few days. The well dried plants were chopped into about 3-5 cm pieces with electric fodder cutter. The dried plant herbage and dry leaves of mulberry were soaked in distilled water 1:5 (1 gram substance in 5 ml distilled water) for 24 hr at room temperature (25-30°C), addition to 1:10 and 1:20 ration (w/v) to prepare sorghum aqueous extracts as described by Cheema and khaliq (2000); Panahyan-e-kivi et al. (2010). Sorghum Methanolic Extracts (SME): the extracts were prepared as described in SAE, While the dried plant herbage and dry leaves were soaked in methanol (2L) for 48 h at room temperature (25-30°C). The methanol extract was evaporated to dryness by using rotary evaporator (50°C) and the dry residue was re-dissolved in distilled water to make up three concentrations (5, 10 and 20%). El-Rokiek et al. (2006).

Herbicides used

Two herbicides Diclofop-methyl (E.C 36%) and Clodinfop propargyl (W.P 15%) belonging to aryloxyphenoxy-propenic group were tested in the present study. These herbicides are widely used in Egypt for controlling target key weeds attacking wheat plants and other crops.

Experimental design and treatments of herbicidal activity.

Three concentrations (5, 10 & 20 %) of aqueous and methanolic extracts were prepared from sorghum plants by using distilled water. The prepared concentrations as well as diclofop- methyl and clodinafop- propargyl at recommended dose 750 ml/fed and 140 gm/fed), respectively, were used under laboratory, greenhouse and semi field conditions to investigate the phytotoxic effects on wheat (*Triticum aestivum* L.) and herbicidal activity wheat weeds, namely wild oat (*Avena fatual* L.) and canary grass (*phalaris minor*). Experiments were arranged in randomized complete block design (RCBD) at four replicates, while field experiments were laid out at three replicates in plots measuring 30 m².

Recording data

Under laboratory conditions: Germination percentage was recorded daily for 10 days. Shoot and root length (cm) data of seedling were recorded with a measuring tape on 8 DAS (Days After Sowing). Seedling dry weight (mg) was recorded on 10 DAS using an electric balance after drying in an oven 70°C for 48 h.

Under greenhouse conditions: For testing germination fifteen seeds were put in plastic pots (height & diameter each about 20 cm filled with sandy soil) and irrigation was continued until plant establishment. The same treatments as used in germination bioassay were applied to seedling in pots after calibration of mini sprayer (Hand Atomizer) as a spray. Control treatment heaving water in the pot was included for comparison. The experiment was laid out in a Completely Randomized Design (CRD) with factorial arrangements in four replicates. The experiment was comprised the different sorghum extracts treatments as: 1st spray at 30 DAS (Days After Sowing); 2nd sprays at 45 DAS; 3rd sprays at 60 DAS and 4th sprays at 75DAS for each concentration, respectively, addition to, herbicide treatments as: Clodinfop- propargyl was sprayed after 30 days from the first irrigation, Diclofop- methyl was sprayed at 3 to 4 leaf stage. Plant dry weight was recorded on 80 DAS with the help of electric balance after drying in an oven 70°C for 48 h. Chlorophyll content was measured by using a Minolta Chlorophyll Meter SPAD 502 plus. Data on the chlorophyll of seedling

were measured with a device for measuring chlorophyll after 8 days of each treatment. Plant height was measured at 80 DAS. Spike length and weight were recorded on 85 days of spraying.

Under semi field conditions: The experiment was laid out in Randomized Complete Block Design (RCBD) having three replicates. The area per plot 100 cm x 44 cm every treatment alone. Seeds of *Triticum aestivum* L. *Avena fatual* L. and *phalaris minor* were mixed and put in per plot. The Crop was cultivated in well prepared seed bed on 10 December, 2012. Data on chlorophyll were measured with a device for measuring chlorophyll at every 8 days after spraying per concentration of each treatment. Plant height, dry weight, plant number, wheat spike of dry weight, spike length and grain weight were measured at 85 days after spraying.

Statistical analysis

The obtained results was statistically analyzed by using Costat analysis of variance technique and least significant difference (LSD) test at the 5 % probability level was applied to compare the treatments mean.

Results and Discussion

Germination Percentage

Data on reduction effect on germination of wheat, wild oat and canary grass were summarized in Figure 1. The obtained data indicated that, there were positive relations between tests concentrations of extracts and germination percentages of wheat. Maximum germination percentage (90%) was observed by 20% aqueous extract of sorghum compared to the control and the tested herbicides. In case of wild oat and canary grass, all tested extracts significantly suppressed germination by 100 % compared to the control and tested herbicides. However, 5% aqueous extract of sorghum showed the minimum inhibition in germination by 68.7 and 48.7 % with wild oat and canary grass, respectively.

Seedling shoots and root length under laboratory conditions:

Wheat, data in Table 1 showed that, all tested aqueous extracts had no negative effect on seedling shoot and root length. These results indicated appropriate selection of the tested extracts on wheat plant. However, the tested SME and herbicides significantly decreased seedling shoot and root length, which revealed a deficiency of selectivity on wheat. Wild oat and canary grass, all tested treatments completely suppressed seedling shoot and root length of wild oat and canary grass compared with the control (Figure 2). With exception of 5% aqueous extract of sorghum showed

(1.94 ±0.8 and 1.54 ±0.9 cm) and (4.94 ±0.8 and 3 ±0.4 cm) for wild oat and canary grass, whereas they were (2.38 ±0.8 and 1.75 ±1.3) and (6.04 ±0.3 and 2.7 ±0.5) in control, respectively.

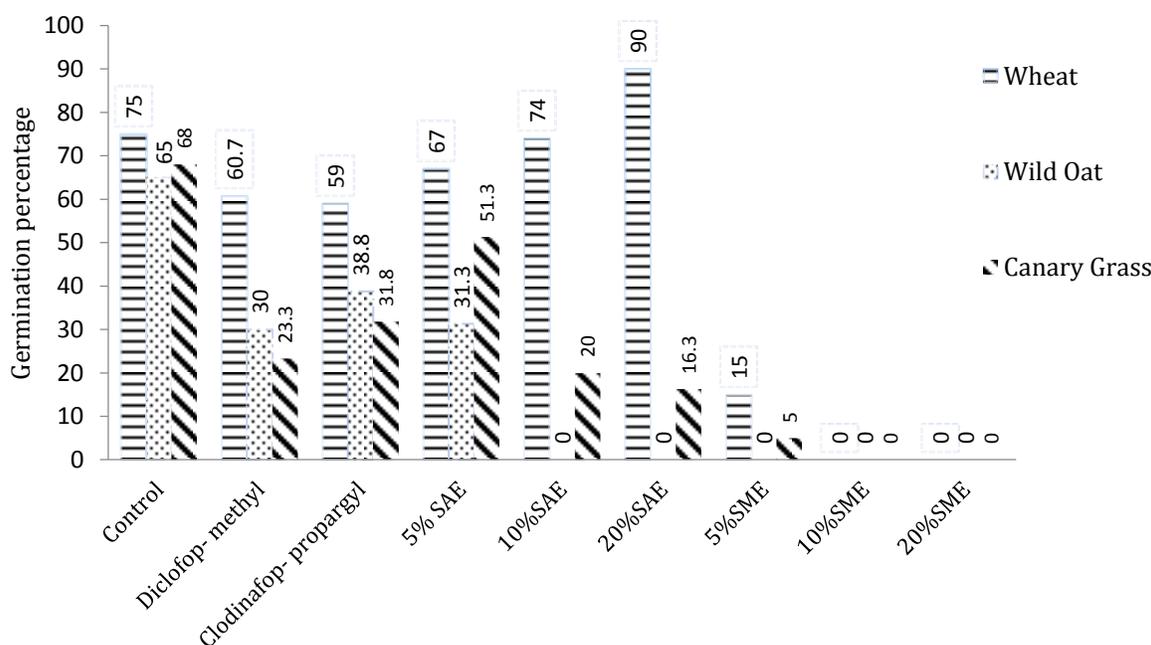


Figure 1. Effect of prepared extracts and conventional herbicides on germination percentage of wheat and associated weeds.

Table 1. Effect of prepared extracts and conventional herbicides on shoot (Shl) and root length (RL) of wheat seedling.

Treatments	5%	10%	20%	Diclofop- methyl	Clodinafop-propergyl	Control	LSD	
SAE	Sh L	2.18± 0.4	0.9± 0.5	6.15± 0.9	0.6± 0.2	0.5± 0.2	4.09± 2.3	2.33
	R L	1.25± 0.4	1.05± 0.9	5.41± 0.7	0.2± 0.2	0.3± 0.1	4.25± 1.9	2.11
SME	Sh L	0.25± 0.1	-	-	-	-	-	2.1
	R L	0.05± 0.04	-	-	-	-	-	1.82

SAE= Sorghum aqueous extract; SME= Sorghum methanolic extract.

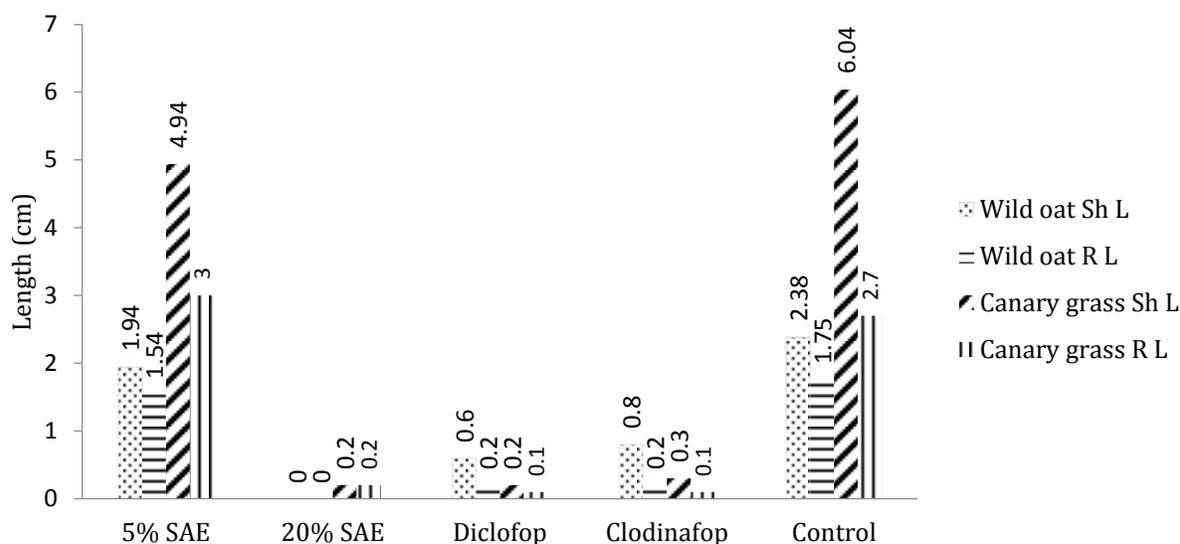


Figure 2. Effect of prepared extracts and conventional herbicides on shoot (ShL) and root length (RL) of canary grass seedling.

Dry Weight

In laboratory, all tested extracts significantly reduced the dry weight of wild oat and canary grass. The heights reductions (100%) were observed for all concentrations of the methanolic extracts, 10 and 20% aqueous extracts compared with test herbicide (Table. 2). In greenhouse, all tested of 10 & 20% sorghum extracts appeared more suppressive in reducing dry weight of canary grass. The highly reductions of dry weight of wild oat were observed with diclofop-methyl then clodinafop-propargyl by 43 and 27.2 %, respectively. Lower reduction percentage were recorded by tested extracts (Table. 3). In semi field conditions, wheat, the obtained result revealed that all tested extracts and herbicides have no negative effect on dry weight. The maximum reduction of wild oat was recorded with SME at 20% (31.42 %) and diclofop-methyl treatment (30.97%). Canary grass, Diclofop-methyl gave maximum reduction (53.85%) and was followed by clodinafop-propargyl (37.12%) and 20% aqueous extract of sorghum (37.46%) (Table 4).

Chlorophyll content

In Greenhouse conditions

Wheat, the obtained result revealed that all tested extracts and herbicides have no negative effect on chlorophyll contents of wheat leaves compared to the untreated plants (control). This finding proved high selectivity of the treatments on wheat plants. Therefore, the tested extracts and herbicides can be applied safely on wheat plants. All sorghum and rice straw extracts reduced

chlorophyll content of wild oat weed. The tested herbicides were showed the highest reduction of chlorophyll content reached 28.2 and 30.7 for diclofop-methyl and clodinafop-propargyl, respectively. Methanolic and aqueous extracts 20% of sorghum decreased chlorophyll content to reach 31.8 and 31.4, respectively. Chlorophyll content of canary grass was suppressed in all the treatments. Diclofop- methyl and clodinafop-propargyl in A4 showed the maximum suppression of chlorophyll content reached 24.5 and 26 SPAD, respectively followed by 20% sorghum extracts (26.5 SPAD) (Table 5).

Table 2. Effect of prepared extracts and conventional herbicides on % dry weight reduction of wheat weed under laboratory condition.

Treatments	wild oat		canary grass	
	SAE	SME	SAE	SME
5%	4.83	100	62.4	83.3
10%	100	100	60.2	100
20%	100	100	87.1	100
Diclofop- methyl	3.2		62.7	
Clodinafop-propargyl	27.41		53.7	

Table 3. Effect of prepared extracts and conventional herbicides on % dry weight reduction of wheat and wheat weeds under greenhouse conditions.

Treatments	wheat		wild oat		canary grass	
	SAE	SME	SAE	SME	SAE	SME
5%	14	10.05	13.1	4.8	18.7	7.1
10%	6.1	6.08	13.1	2.1	30.3	35.3
20%	4.5	4.5	15.9	15.9	35.2	36
Diclofop- methyl	5.2		27.2		39.8	
Clodinafop-propargyl	3.4		43		33.2	

Table 4. Effect of prepared extracts and conventional herbicides on % dry weight reduction of wheat and wheat weeds under semi field conditions.

Treatments	wheat		wild oat		canary grass	
	SAE	SME	SAE	SME	SAE	SME
5%	7.69	10.05	13.72	8.85	22.07	17.73
10%	1.71	5.13	28.32	18.14	24.41	29.77
20%	15.61	1.28	27.43	31.42	37.46	33.11
Diclofop- methyl	36.32		22.12		37.12	
Clodinafop-propargyl	12.39		30.97		37.12	

Table 5. Effect of sorghum extracts and conventional herbicides on chlorophyll content of wheat, wild oat and canary grass under greenhouse conditions after four applications.

Treatments	Chlorophyll content (SPAD units) after different applications					
	Wheat		wild oat		canary grass	
	Aqueous	Methanolic	Aqueous	Methanolic	Aqueous	Methanolic
	<i>Concentration</i>					
5%	36.6±1.8	37.8±1.0	34.5± 0.4	33.1± 3.0	28.8± 3.5	30.1± 4.8
10%	39.9± 0.8	38±1.5	32.8± 0.6	32.3± 0.7	27.6± 1.5	27± 4.3
20%	41.9± 1.1	40±0.7	31.4± 0.9	31.8± 1.4	26.5± 1.8	26.6± 2.3
Clodinafop-propargyl	41± 1.0		28.2± 0.9		26± 1.1	
Diclofop- methyl	41.1± 0.9		30.7± 2.5		24.5 ± 0.9	
Control	42.2± 1.0		32.9± 1.3		29.3 ± 2.8	

In Semi field

Chlorophyll contents of wheat leaves after successive application of the tested extract are tabulated in Table 6. The obtained result revealed that all tested extracts and herbicides have no negative effect on chlorophyll contents of wheat leaves compared to the untreated plants (control). The highest chlorophyll content in A3 was observed with 20% of sorghum extracts to reach 47.3, and followed by clodinafop-propargyl and diclofop-methyl to reach 47.2 and 46, respectively. Wild oat, the chlorophyll content in A3 was reduced to reach 24.5 as a result of treatment with diclofop-methyl and was followed by clodinafop-propargyl and 20% of tests extracts. There were no significant effects concerning the interaction between concentrations and applications. Chlorophyll content of canary grass was significantly decreased by all treatments as compared to control. Maximum suppression was obtained with clodinafop-propargyl and diclofop-methyl in A3 reach 18.9 and 18.5 respectively, and was followed with all tested extracts.

*Plant height**In Green house*

All tested extracts had no negative effect on plant height of wheat compared to the untreated plants (Figure 3). This finding proved high selectivity of the treatments on wheat plants. Therefore, the tested extracts and herbicides can be applied safely on wheat plants. Plant height of wild oat was significantly decreased by all treatments. Maximum reduction was observed at clodinafop-

propargyl treatment by 19.9 cm followed by 24.5 cm reduction for diclofop-methyl and followed 20% tested extracts compared with control. For Canary grass, maximum suppression was observed by clodinafop-propargyl by 29.8 cm and was followed by 31.7 cm with 20% methanolic extract of sorghum also followed 20% tested extracts. Plant height showed non-significant effect between concentrations of tested extracts at 5 and 10%.

Table 6. Effect of sorghum extracts and conventional herbicides on chlorophyll content of wheat, wild oat and canary grass under semi field conditions after three applications.

Treatments	Chlorophyll content (SPAD units) after different applications					
	Wheat		wild oat		canary grass	
	Aqueous	Methanolic	Aqueous	Methanolic	Aqueous	Methanolic
	Concentration					
5%	40.6± 0.8	43.3± 2.5	34.4± 0.9	35.3± 1.1	28.5± 0.2	28.9± 0.9
10%	43.7± 1.0	45.4± 0.5	31.3± 1.2	33.6± 0.8	24± 0.1	24.8± 0.8
20%	47.3± 0.3	47.2± 1.8	30.3± 1.7	32.2± 1.6	22.3± 1.5	23± 1.1
Clodinafop-propargyl	47.2± 0.9		26.6± 1.8		18.9± 1.3	
Diclofop- methyl	46± 1.2		24.5± 1.0		18.5± 13.1	
Control	46± 0.4		37.6± 1.3		30.2± 0.4	

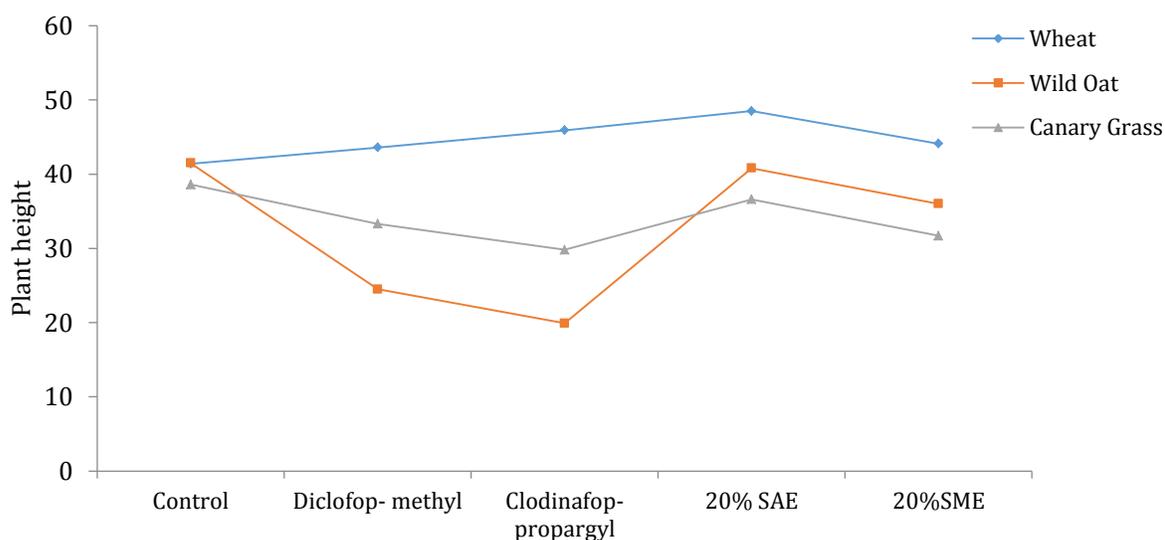


Figure 3. Effect of prepared extracts and conventional herbicides on plant height (cm) of wheat and associated weeds under greenhouse conditions.

In Semi field

For wheat, the obtained results revealed that all tested extracts and herbicides have no negative effect on plant height of wheat compared to the untreated plants (control). This finding proved high selectivity of the treatments on wheat plants. Plant height of wild oat was not significantly affected with all treatments. The maximum suppression was observed by diclofop-methyl and clodinafop-propargyl treatments to reach 28.9 and 29.6 cm, respectively followed by 20% aqueous extracts of sorghum reached 27.4 cm. In case of Canary grass, Clodinafop-propargyl treatment showed more suppressive effect in reducing plant height of field reached 26.6 cm, followed by 28.8 cm for diclofop-methyl compared to the control (Figure 4).

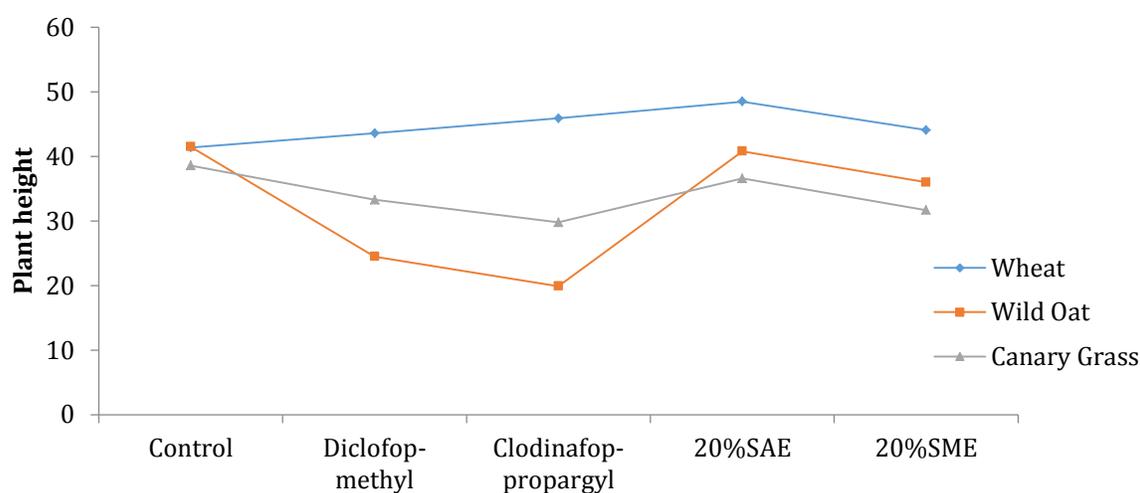


Figure 4. Effect of prepared extracts and conventional herbicides on plant height (cm) of wheat and associated weeds under semi field conditions.

Plant Number (under Semi Field Conditions)

Wild oat, Data in Table 7 showed that the maximum reduction in plant number (81.1%) was obtained with diclofop-methyl followed by clodinafop-propargyl (77%) and followed by the tested extracts. Canary grass, As shown in Table 7, Diclofop-methyl and clodinafop-propargyl showed more suppressive effect in reducing of plants number by 88.5 and 78.7%, respectively, compared to the tested extracts.

Spike length and spike weight of treated wheat

Green house conditions, Maximum spike length (10 cm) was observed in pots treated with 20% aqueous extracts of sorghum compared to the control. Semi field conditions, Maximum spike length and grain weight were recorded in plots treated with 20% aqueous extract sorghum to reach 7.6

cm and 23.8 mg, respectively. In this respect, 20% SME showed the maximum grain weight (16.7 mg) of wheat. The obtained results showed good selectivity of the treatments on wheat plants (Table 8). Reviewing the obtained data it could be concluded that the aqueous and methanolic extracts of sorghum had a great inhibition effect on wild oat and canary grass germination. Such data are in harmony with Chung et al. (2001) and Mahmood et al. (2010). Some research such as Afridi et al. (2013) found that, allelopathic effect of different concentrations was not significant for germination percentage, but germination rate and mean germination time decreased significantly by increasing the concentration of allelopathic extracts.

Table 7. Effect of prepared extracts and conventional herbicides on plant number of wild oat and canary grass under semi field conditions.

Treatments	wild oat				canary grass			
	SAE	% reduction	SME	% reduction	SAE	% reduction	SME	% reduction
Concentration								
5%	29±4.85	21.6	17.5±2.35	52.7	28.5± 3.54	6.6	27.5±3.22	9.8
10%	17± 1.41	54.1	19.5± 0.71	47.3	31.5± 2.48	3.27	21.5±2.64	29.5
20%	14± 2.82	62.2	10.5±0.94	71.6	30±4.98	1.63	22± 3.31	27.8
Clodinafop - propargyl	8.5± 0.71		77		6.5± 2.13		78.7	
Diclofop- methyl	7± 1.21		81.1		3.5± 0.74		88.5	
Control		37± 4.23				30.5± 2.12		

Regarding the effect of the tested extracts on shoots and root length not had any negative effects on seedling shoot and root length, meanwhile completely suppressed seedling shoot and root length of wild oat and canary grass. This find have a similar trend with Randhawa et al. (2002) who found that, the root length decreased with increase of concentration of the extract, the root growth reduction by sorghum water extracts could be attributed to inhibitory effects of sorghum allelopathic substances present in the extract. Also, Guenzi and McCalla, 1966; Haskins and Gorz, 1985; Nimbal et al. 1996) discussed the potential of such extracts as effective control agent at higher rates, and reported that this may be due to increasing concentration of allelopathic compounds present in sorghum such as m-coumaric acid, caffeic acids, gallic acid, protocateuic acid, syringic acid, vanillic acid, phydroxybenzoic acid, p-coumaric acid, benzoic acid and ferulic acid. The effect of conventional herbicides on reduction of dry weight matter of exposed weeds were

emphasized by different researchers such as Cheema et al. 2001; Shehzad et al. 2012. Clodinafop-propargyl showed the maximum reduction of wild oat and canary grass. On the contrary, with the wheat plant in wheat field (Khatam et al. 2013). Maximum value of plant heights (cm) at maturity stage were recorded in Topik 15%WP in wheat field (Bibi et al. 2008). The obtained data are contrary with the findings of Marwat et al. (2005) and Arif et al. (2015), who reported reduction in plant height under the treatments of concentrated sorghum aqueous extracts may be attributed to the selective behavior of allelochemicals present in these extracts. However, they are similar with results of Cheema and khaliq, (2000), Cheema et al. (2001), (Chung et al. 2001), Hassan et al. (2005) and Shehzad et al. (2012).

Table 8. Effect of prepared extracts and conventional herbicides on spike length (SL), spike weight (SW) and grain weight (GW) of wheat.

Treatments	Under greenhouse				Under semi field					
	SAE		SME		SAE		SME			
	SL	SW	SL	SW	SL	SW	GW	SL	SW	GW
	Concentration									
5%	7.6	4.8	7.8	4.8	5.6	19.9	7.6	6.4	19.4	9.6
	± 0.3	± 0.9	± 0.5	± 0.3	± 1.3	± 1.2	± 7.4	± 0.3	± 0.9	± 1.6
10%	9.7	4.6	8	5.1	6.7	22.1	10.7	6.5	22.5	14.1
	± 0.8	± 1.0	± 0.7	± 0.5	± 0.3	± 1.0	± 5.4	± 1.0	± 1.3	± 0.6
20%	10	5.1	9.2	6	7.6	23.8	12.8	7.3	23	16.7
	± 0.2	± 0.3	± 0.2	± 0.6	± 0.2	± 0.6	± 0.3	± 0.0	± 3.7	± 0.8
Clodinafop-propargyl	8.2± 0.4		6.5± 0.3		6.6± 0.1		23.1± 0.8		12.9± 0.4	
Diclofop-methyl	8.2± 0.3		6.7± 0.5		6.9± 0.8		23.5± 1.5		13.5± 0.6	
Control	8.3± 0.5		5± 0.5		6.1± 0.4		22.9± 1.7		13.6± 0.4	

Conclusion

These finding conforming the potential of sorghum extracts as biocontrol agents to accompanied weeds of wheat.

Conflicts of Interest

Authors confirm that there is no conflict of interest to disclose.

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