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ALLELOPATHIC EFFECTS OF SORGHUM AND SUNFLOWER WATER EXTRACTS ON GERMINATION AND SEEDLING GROWTH OF RICE (*ORYZA SATIVA* L.) AND THREE WEED SPECIES

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ABSTRACT

Laboratory experiments were conducted to evaluate the allelopathic effects of water extracts of sorghum and sunflower alone and in combination on the germination and seedling growth of rice and weeds viz: *Trianthema portulacastrum*, *Dactyloctenium aegyptium* and *Eleusine indica*. Distilled water treatment was included as control. In first experiment, the germinated seeds of rice and weeds were counted every day and removed from petri dishes. Whereas in second experiment, rice and weed seeds were sown in sand culture to assess their seedling growth. Experiments were laid out in completely randomized design under factorial arrangement. Sorghum and sunflower water extracts when applied in combination caused maximum inhibitory effects on time taken to 50 % germination, mean germination time of *E. indica* seeds and germination index of *T. portulacastrum* seeds as compared to the sole application of these water extracts. Water extracts of sorghum, sunflower when applied alone and in combination increased the root, shoot length and the seedling biomass of rice over control. Combined application of sorghum and sunflower water extracts caused maximum reduction in root length of *T. portulacastrum*. It can be concluded that combined application of sorghum and sunflower water extracts has overall more inhibitory effects on the germination of rice, *T. portulacastrum*, *D. aegyptium* and *E. indica* when compared to their sole application.

Keywords: Allelopathy, *Dactyloctenium aegyptium, Eleusine indica,* germination, *Oryza sativa*, seedling growth, *Trianthema portulacastrum* and weed.

INTRODUCTION

Weeds can be controlled by variety of methods like cultural, mechanical, chemical and biological methods. Keeping in view the health of environment, use of the biological or natural methods for weed control is strongly advocated. Allelopathy is defined as the direct or indirect harmful or beneficial effects of one plant on another through the release of certain chemical compounds into the environment (Ashrafi *et al*. 2008). Allelopathy has been recognized as a natural weed control option. Different crops have allelochemicals which could be used for inhibiting weeds. Sorghum is one of the potential allelopathic crops having a number of allelochemicals at maturity. Ahmad *et al*. (2000) has reported inhibitory effects of sorghum on different weed species. Herbicidal potential of allelopathic grasses against *Parthenium* weed evaluated by Anjum *et al*. (2005) and Javaid *et al*. (2005) have also provided very encouraging results. Sunflower crop is also well known for its allelopathic effects (Ashrafi *et al*. 2008). Several phenols and terpenes have been reported in different sunflower cultivars (Macias *et al*. 2004). Combined application of water extracts of sorghum and sunflower also affects the growth of crops and weeds.

Trianthema portulacastrum is one of the serious kharif weeds in Pakistan (Randhawa *et al*, 2002). *Dactyloctenium aegyptium* is a weed of the tropics and is among the most common grass weeds (Ismail and Chong, 2009). *Eleusine indica* is reported in 46 crops in 60 countries and is widely distributed in tropics and subtropics. It is considered as one of the most important grassy weeds of rice, particularly in rain-fed environments (Bhagirath *et al*. 2008). The above mentioned weeds pose a serious threat to rice yield in non traditional rice growing areas of Pakistan. Rice is life for more than half of the world population. It is one of the most important cereal crops in Pakistan. The information on allelopathic effects of sorghum and sunflower alone and in combination on germination and seedling growth of rice and the above mentioned weeds is scarce. Therefore, the present study was designed to evaluate the allelopathic effects of water extracts of sorghum and sunflower alone and in combination on germination of rice crop, *T. portulacastrum, D. aegyptium* and *E. indica*.

MATERIALS AND METHODS

Laboratory experiments were conducted during 2009 to evaluate the allelopathic effects of sorghum and sunflower alone and in combination on the germination of rice and weeds viz: *T. portulacastrum, D. aegyptium* and *E. indica*. The experiments were laid out in factorial arrangement under completely randomized design with

three replications. The germination experiment was done in petri dishes while seedling growth was checked in the sand culture in the laboratory. Sorghum and sunflower sticks were harvested at maturity in the field and dried for few days under shade. The dried plants of sorghum and sunflower were cut into small pieces with fodder cutter and dried in an oven at 70 °C for 48 hours. The oven dried herbage of sorghum and sunflower was then ground in the grinder and filtered through a 40 mesh sieve. The ground material of both the crop plants was soaked in distilled water (1: 20 w/v) individually for 24 hours at room temperature (Hussain and Gadoon, 1981) to obtain water extracts of sorghum and sunflower. These were then filtered through filter paper Whatman # 42 to separate the solid materials and were used in experiment as per treatment as fresh water extracts.

Experiment 1: Allelopathic effects of sorghum and sunflower water extracts alone and in combination on the germination of fine rice and weeds: The water extracts of sorghum and sunflower were used to test the seed germination response of rice and weeds using filter paper Whatman # 42 as a medium of germination in 9 cm petri dishes. All the petri dishes were placed in germinator at 30 °C. In each petri dish, fifty seeds of rice and 100 seeds of weeds were placed as per treatment. Water extracts of sorghum and sunflower were applied in petri dishes along with distilled water treatment as a control. Distilled water or water extracts of sorghum and sunflower as per treatment were applied subsequently to avoid drying out of filter paper during the course of experiment.

Germination was calculated by counting and removing the germinated seeds. Germination was observed daily in accordance with the methods of Association of Official Seed Analysis (1990). Time taken to 50% germination (T_{50}) was calculated by the formula given by Coolbear *et al.,* (1984) and modified by Farooq *et al.,* (2004).

$$T_{50} = \frac{ti + (N/2 - ni)(tj - ti)}{(nj - ni)}$$

Where N is the final number of germinated seeds while nj and ni are the cumulative number of seeds germinated by adjacent counts at times tj and ti, respectively, where ni < N/2 < nj. The germination index (GI) was calculated as given by Association of Official Seed Analysis (1990) using the formula

$$GI = \frac{\text{No. of germinated seeds}}{\text{Days of first count}} + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Mean Germination Time (MGT) was calculated by using the equation of Ellis and Roberts (1981).

$$MGT = \frac{\sum Dn}{\sum n}$$

Where n is the number of seeds that had germinated on day D and D is the number of days counted from the beginning of germination. Germination energy (GE) was recorded on the 4th day after planting. It is the percentage of germinating seeds 4 days after planting relative to the total number of seeds tested (Farooq *et al*. 2005). Time to start germination of rice and weeds was also recorded.

Experiment 2: Allelopathic effects of water extracts of sorghum and sunflower alone and in combination on the seedling growth of fine rice and weeds: Ten seeds of rice and weeds were placed in beakers filled with sand for each treatment of each replication. Water extracts and distilled water were added to each beaker as per treatment. The beakers were incubated at 30 °C. Sorghum and sunflower water extracts and distilled water were added subsequently according to the treatment when required. Root and shoot length of seedlings of rice and weeds were measured at the end of the experiment. Rice and weed seedlings were cut into roots and shoots and were oven dried till constant weight to calculate root and shoot dry weight per seedling of rice and weeds.

Coefficient of uniformity of emergence (CUE) was calculated according to the following formulae of Bewley and Black (1985):

$$CUE = \sum n / \sum [(t' - t)^2 n]$$

Where t is the time in days, starting from day 0, the day of sowing and n is the number of seeds completing emergence on day t and t' is equal to MET.

Seedling vigor index (SVI) was calculated using the following formula of Abdul-baki and Anderson (1973)

SVI = germination/emergence% × radicle length

Pooled mean values were separated using least significant differences (LSD) at the 0.05 probability level. The data collected was analyzed by using the Fisher's analysis of variance and LSD at 5% probability was used to compare the treatments means (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

A) Germination parameters: An overall inhibitory effect of sunflower water extract was more than sorghum water extract on the T_{50} of rice and weeds except *E. indica* under study might indicate more inhibitory effects of allelochemicals in water extract of sunflower than in sorghum. Results are in line with the findings of Khaliq *et al*., (2009) who also reported more inhibitory effects of sunflower water extract than water extract of sorghum on the germination of *Cichorium intybus*. While the combined application of water extracts of both crop plants was statistically same except for the T_{50} of *D. aegyptium*. Rice and weed seeds also showed significant differences for T_{50} and the maximum time was taken by *E. indica*. There was non-significant difference for T_{50} of seeds of rice and weeds where distilled water was applied with minimum T_{50}. Application of distilled water reduced the time to 50 % germination (T_{50}) while maximum delay in T_{50} of *D. aegyptium* by sunflower water extract and in

E. indica by combined application of sorghum and sunflower water extracts , respectively, might be due to their allelopathic effects on both weeds. Among the water extracts application to *T. portulacastrum* the maximum inhibition in T_{50} was found where sunflower alone and sorghum and sunflower water extracts were applied in combination. While, significantly maximum delay in T_{50} of *D. aegyptium* was noted where water extract of sunflower was applied. Combined application of sorghum and sunflower water extracts to seeds of *Eleusine indica* was statistically similar to sole application of sunflower water extract. Sole application of water extracts of sorghum and sunflower to rice and *T. portulacastrum* seeds showed statistically similar T_{50} while the effect of sorghum water extract on T_{50} of *D. aegyptium* and *E. indica* was significantly different from each other. Seed of *D. aegyptium* varied significantly with application of each water extract of sorghum, sunflower, combined application of water extracts and distilled water (Table 1).

Application of crop water extract alone and in combination differed significantly for germination index (GI) with maximum where sorghum water extract was applied. Rice and weed seeds also showed significant differences for GI with maximum in *D. aegyptium*. The interactive effect of both the factors was also significant and the maximum germination index (GI) was found where seeds of *D. aegyptium* were subjected to application of distilled water (W_3E_4) whereas, the minimum was found where *T. portulacastrum* seeds were subjected to combined application of both crop water extracts (W_2E_3). There was significant difference between GI of rice and weed seeds applied with distilled water and crop water extracts. Among the water extracts, the GI of rice seed was inhibited the most by application of sunflower water extract (W_1E_2). Effect of sorghum water extract and combined application of crop water extracts on seeds of weeds was non-significant for GI but significantly different from germination index of rice seeds subjected to application of sorghum water extract (Table 2). Combined application of water extracts of both crops decreased germination index (GI) of all weeds under test as compared to their sole application. It could be attributed to more inhibitory effects of allelochemicals of both extracts when combinely applied.

Maximum delay in germination of *D. aegyptium* caused by sunflower water extract shows that sunflower water extract might have highest allelopathic activity in *D. aegyptium* among weeds under test for mean germination time. While, mean germination time of *E. indica* was delayed the most by combined application of water extracts of both crops as compared to water extracts of sorghum, sunflower alone or distilled water application. It could be attributed to more allelopathic effect of crop water extracts when applied in combination as compared to their sole application. Results are quite in accordance with the findings of Panasiuk, 1986 who suggested that young sorghum seedlings produce allelochemicals that can influence the germination of a number of weeds. The crop water extract alone and in combination differed significantly for germination with minimum where crop water extracts of sorghum and sunflower were applied combinely (E_3). Germination of *D. aegyptium* and *E. indica* showed statistically similar results when applied with water extracts of sorghum and sunflower separately but combined application of these water extracts significantly reduced the germination of *D. aegyptium*. The minimum mean germination time (MGT) was noted in distilled water application to seeds of all weeds and rice which could not reach the level of significance with each other. There was a significant difference between MGT of rice and weeds subjected to water extracts application and control except where seeds of rice and *T. portulacastrum* were treated with sorghum water extract (Table 3).

Application of sorghum water extract showed similar results when applied to *D. aegyptium* and *E. indica* seeds but significantly different from germination of *T. portulacastrum* when treated with sorghum water extract. The significant reduction in germination by sunflower water extract among rice and 3 weeds was found in *T. portulacastrum* (Table 4). Maximum reduction in germination of *T. portulacastrum* by application of sorghum water extract among rice and weed seeds under study shows that sorghum water extract has maximum inhibitory effects on germination of *T. portulacastrum* compared to sole application of sunflower water extract or combined application of both extracts. The effect of sorghum water extract was maximum for germination of *T. portulacastrum* compared to other weeds. Randhawa *et al*., (2002) also reported significant reduction in germination of *T. portulacastrum* by application of sorghum water extract. Water extract of sunflower showed maximum reduction in germination of *T. portulacastrum* over control among all the weeds and rice seeds. Results are supported by the findings of Ashrafi *et al*. (2008) who reported significant inhibition of wild barley seed germination by application of extracts from sunflower when compared with control.

Application of crop water extract alone and in combination showed a significant effect on germination energy (GE) with minimum where combined application of sorghum and sunflower water extracts was done and maximum time taken to start germination was found where sunflower water extract was applied. Rice and weed seeds also showed significant differences for GE and time to start germination with minimum GE and time to start germination was recorded in case of *E. indica*. Combined application of water extracts of sorghum and sunflower resulted in least germination energy (GE) of all weeds and rice compared with sole application of sorghum and sunflower water extracts. Whereas, the maximum GE was found where distilled water was

applied to rice and weed seeds (Fig. 1). Sunflower water extract when applied to seeds of rice and weeds caused maximum delay in time to start germination while the application of distilled water to seeds of rice and weeds showed least time to start germination (Fig. 2).

Table 1: Effect of water extracts of sorghum and sunflower alone and in combination on time taken to 50 % germination (T_{50}) by seed of rice and three weed species

	Sorghum water extract (E_1)	Sunflower water extract (E_2)	Sorghum + sunflower water extracts (E_3)	Distilled water (E_4)	Mean
Oryza sativa (W_1)	4.04e	6.89bc	6.99bc	2.89f	5.21C
T. portulacastrum (W_2)	4.47e	7.52a	7.38a	2.73f	5.52BC
D. aegyptium (W_3)	5.73d	8.04a	6.92bc	2.66f	5.84B
E. indica (W_4)	6.74c	7.84a	8.03a	3.14f	6.44A
Mean	5.24B	7.57A	7.33A	2.86C	
LSD 5%	Extract= 0.442		Weed= 0.442	Interaction = 0.885	

Table 2: Effect of water extracts of sorghum and sunflower alone and in combination on germination index (GI) of seed of rice and three weed species

	Sorghum water extract (E_1)	Sunflower water extract (E_2)	Sorghum+ sunflower water extracts (E_3)	Distilled water (E_4)	Mean
Oryza sativa (W_1)	32.05b	20.41cd	22.41c	49.78a	31.16A
T. portulacastrum (W_2)	15.84d	13.67d	11.89d	51.01a	23.10B
D. aegyptium (W_3)	18.47cd	16.24d	14.36d	51.56a	25.16B
E. indica (W_4)	18.04cd	17.00cd	14.44d	45.77a	23.66B
Mean	21.10B	16.83C	15.77C	49.38A	
LSD 5%	Extract= 3.001		Weed=3.001	Interaction =6.001	

B) Seedling parameters: The maximum root length of rice was noted by application of sunflower water extract. Root length of *T. portulacastrum* was minimum where water extracts of sorghum and sunflower were applied together. Root length of *D. aegyptium* and *E. indica* was not affected by type of water extracts whether alone or in combination, compared with control. Seedlings of *E. indica* when applied with sole sorghum and sunflower water extracts were statistically alike to distilled water treatment (Table 5). Increase in root length of rice seedlings over control by application of water extracts of sorghum, sunflower alone and in combination show stimulatory effects of these extracts on root length of rice. Maximum reduction in root length of *T. portulacastrum* was noted by the application of water extracts of sorghum and sunflower compared to distilled water treatment. Results are supported by the findings of Khaliq *et al*., (2009) who reported evident suppressive effects of water extracts of sorghum and sunflower on root length of *C. intybus* as compared with control. Reduction in root length by application of sorghum water extract might be due to inhibitory effects of allelopathic compounds present in the extracts of sorghum and sunflower. Results support the findings of Randhawa *et al*. (2002) who recorded significant reduction in root length of *T. portulacastrum* by the application of sorghum water extract. Root length of *D. aegyptium* was not significantly affected by application of water extracts of sorghum and sunflower alone and in combination however there was significant difference from distilled water application. Combined application of sorghum and sunflower water extracts significantly inhibited the root length of *E. indica* over control.

Increase in shoot length of rice over control by application of sorghum, sunflower alone and in combination show that stimulatory allelochemicals in these extracts might be the reason. Significant reduction in shoot length of *T. portulacastrum* over control by application of water extracts could be attributed to inhibitory effects of allelochemicals in these extracts. Shoot length of *T. portulacastrum* was significantly reduced by application of sorghum water extract (Randhawa *et al*. 2002) and sunflower water extract (Ashrafi *et al*. 2008) over control. The application of water extracts of sorghum and sunflower alone and in combination had no significant effect on shoot length of *T. portulacastrum*, *D. aegyptium* and *E. indica* but significantly different from distilled water control (Table 6).

The interactive effect was significant and the maximum root dry weight per seedling was noted where rice seeds were subjected to application of water extracts of sunflower (W_1E_2). Significant increase in root dry weight per seedling of rice by application of water extracts of sorghum, sunflower alone and in combination compared with control indicate the presence of

stimulatory allelochemicals. Increase in root dry weight per seedling of rice was due to increase in thickness and length of roots over control. Application of water extracts of sorghum and sunflower alone and in combination had statistically similar effects on root dry weight per seedling of all weeds under test when compared with distilled water control. Results are not supported by the findings of Ashrafi *et al*, 2008 who reported significant reduction in root dry weight of wild barley by application of sunflower water extract. This contradictory result might be attributed to difference in weed species under test. Whereas, the root dry weight per seedling of *T. portulacastrum*, *D. aegyptium* and *E. indica* could not reach the level of significance by application of water extracts of sorghum and sunflower alone and in combination and control treatment (Table 7). Increase in shoot dry weight per seedling of rice over control shows that stimulatory allelopathic compounds might be responsible for this increase. Furthermore,, the increase in shoot dry weight per seedling can also be attributed to increase in thickness and length of shoots of rice over control. Shoot dry weight per seedling of all the weeds were statistically at par with their respective control treatment (Table 8).

Table 3: Effect of water extracts of sorghum and sunflower alone and in combination on mean germination time (MGT) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	5.57d	8.39b	8.79ab	4.71de	6.87B
T. portulacastrum (W_2)	5.58d	8.71ab	8.52ab	4.48e	6.83B
D. aegyptium (W_3)	7.20c	9.46a	8.19bc	4.49e	7.34AB
E. indica (W_4)	8.29bc	9.17ab	9.26ab	4.78de	7.88A
Mean	6.66B	8.94A	8.69A	4.62C	
LSD 5%	Extract= 0.527	Weed=0.527	Interaction = 1.054		

Table 4: Effect of water extracts of sorghum and sunflower alone and in combination on germination (%) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	84.00b	83.33bc	82.67bc	92.00a	85.50A
T. portulacastrum (W_2)	64.00d	67.33d	68.67cd	92.00a	73.00C
D. aegyptium (W_3)	76.00c	76.67bc	67.33d	93.33a	78.33B
E. indica (W_4)	78.00bc	80.00bc	72.00cd	90.00ab	80.00B
Mean	75.50BC	76.83B	72.67C	91.83A	
LSD 5%	Extract= 3.995	Weed=3.995	Interaction = 7.991		

Table 5: Effect of water extracts of sorghum and sunflower alone and in combination on root length (cm) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	5.53a	5.60a	5.23ab	3.90b	5.07A
T. portulacastrum (W_2)	2.47c	2.57bc	2.10cd	3.70bc	2.71B
D. aegyptium (W_3)	1.73cd	1.90cd	1.50cd	3.53bc	2.17BC
E. indica (W_4)	1.33cd	1.73cd	0.97d	2.57bc	1.65C
Mean	2.77AB	2.95AB	2.45B	3.43A	
LSD 5%	Extract= 0.699		Weed= 0.700	Interaction = 1.399	

Combined application of sorghum and sunflower water extract significantly reduced the shoot dry weight per seedling of *T. portulacastrum* over control. While there was non-significant difference of application of water extracts of sorghum and sunflower alone and in combination on shoot dry weight of *D. aegyptium* and *E. indica* when compared with control. Results are in consonance with the findings of Leather (1983) who reported that the growth of grass weeds except green foxtail was unaffected by leachates of sunflower. He further pointed out that sunflower leachates inhibited growth of most broadleaf weeds like

velvetleaf growing in sand culture by 40 to 60%. Reduction in germination and emergence of small grain crops due to allelopathic effects of Asteraceae species has been reported by Muehlchen *et al*. 1990. Several allelochemicals have been isolated from sunflower residues for example allyl-isothiocyanate (ITC) suppressing the germination and growth of many grass species (Vaughn and Boydston, 1997). Uremis *et al*. (2005) reported inhibitory effects of water extracts of different Brassica spp. on germination and growth of cutleaf ground cherry weed (*Physalis angulata* L.). The maximum CUE of rice and all weeds under test was found when their seeds were subjected to application of sorghum water extract (Fig. 3). Maximum SVI of all weeds was found where these weeds were subjected to application of distilled water (Fig. 4).

It can be concluded from the studies that sorghum and sunflower water extracts possess innate allelopathic potential for their effects on *T. portulacastrum, D. aegyptium* and *E. indica*. Combined application of sorghum and sunflower water extracts affected the germination and seedling growth of weeds and rice more than their sole application. The overall inhibition in germination and seedling growth of *T. portulacastrum, D. aegyptium* and *E. indica* was highest by combined application of sorghum and sunflower water extract. The inhibitory substances in crop water extracts of sorghum and sunflower could be used as a potent bio herbicide.

Table 6: Effect of water extracts of sorghum and sunflower alone and in combination on shoot length (cm) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	4.73a	4.90a	4.83a	3.47b	4.48A
T. portulacastrum (W_2)	1.90c	2.00c	1.77c	3.23b	2.23B
D. aegyptium (W_3)	2.00c	2.07c	1.87c	3.23b	2.29B
E. indica (W_4)	1.53c	1.83c	1.43c	2.30bc	1.78B
Mean	2.54ns	2.70	2.48	3.06	
LSD 5%	Extract= ns		Weed= 0.585	Interaction = 1.170	

Table 7: Effect of water extracts of sorghum and sunflower alone and in combination on root dry weight (mg) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	13.25a	13.67a	12.78a	5.61b	11.33A
T. portulacastrum (W_2)	0.63b	0.21b	0.47b	5.46b	1.69B
D. aegyptium (W_3)	1.26b	1.24b	1.13b	5.68b	2.33B
E. indica (W_4)	0.18b	0.27b	0.34b	1.09b	0.47B
Mean	3.83ns	3.85	3.68	4.46	
LSD 5%	Extract= ns		Weed=2.757	Interaction = 5.514	

Table 8: Effect of water extracts of sorghum and sunflower alone and in combination on shoot dry weight (mg) of seed of rice and three weed species

	Sorghum water extract (E_1)	**Sunflower water extract (E_2)**	**Sorghum+ sunflower water extracts (E_3)**	**Distilled water (E_4)**	**Mean**
Oryza sativa (W_1)	8.15a	8.35a	7.48a	4.53b	7.13A
T. portulacastrum (W_2)	3.35bc	3.05bc	1.43c	4.43b	3.04B
D. aegyptium (W_3)	1.19c	1.29c	1.06c	3.74bc	1.82BC
E. indica (W_4)	0.86c	0.99c	0.67c	2.08bc	1.15C
Mean	3.39ns	3.42	2.65	3.69	
LSD 5%	Extract= 1.452		Weed= 1.452	Interaction = 2.903	

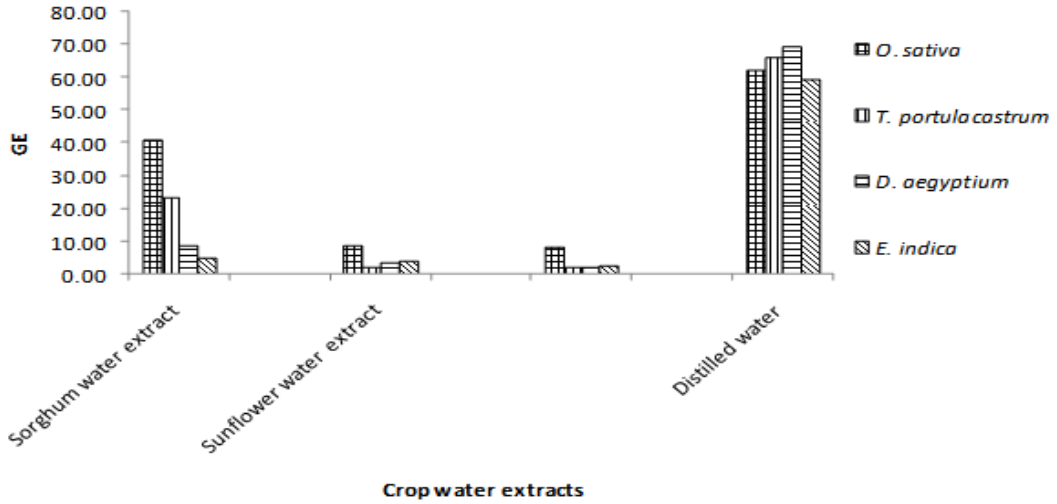

Fig. 1: Effect of water extracts of sorghum and sunflower alone and in combination on Germination energy (GE) of rice and three weed species.

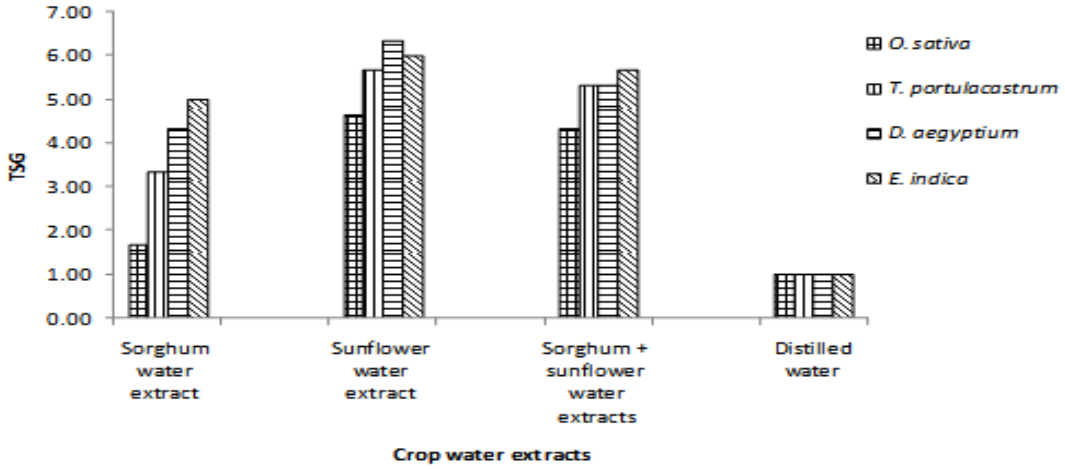

Fig. 2: Effect of water extracts of sorghum and sunflower alone and in combination on Time taken to start germination (TSG) by seed of rice and three weed species.

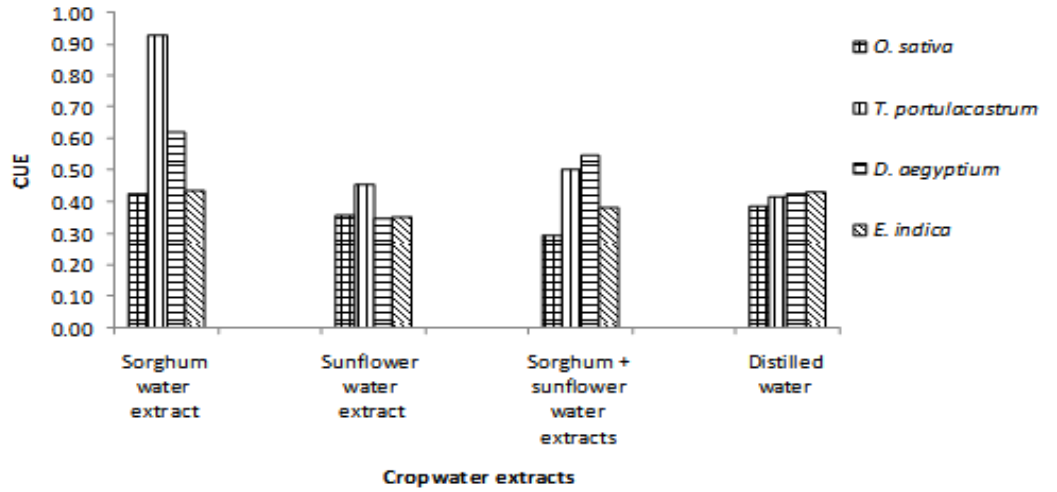

Fig. 3: Effect of water extracts of sorghum and sunflower alone and in combination on Co efficient of uniformity of emergence (CUE) of rice and three weed species.

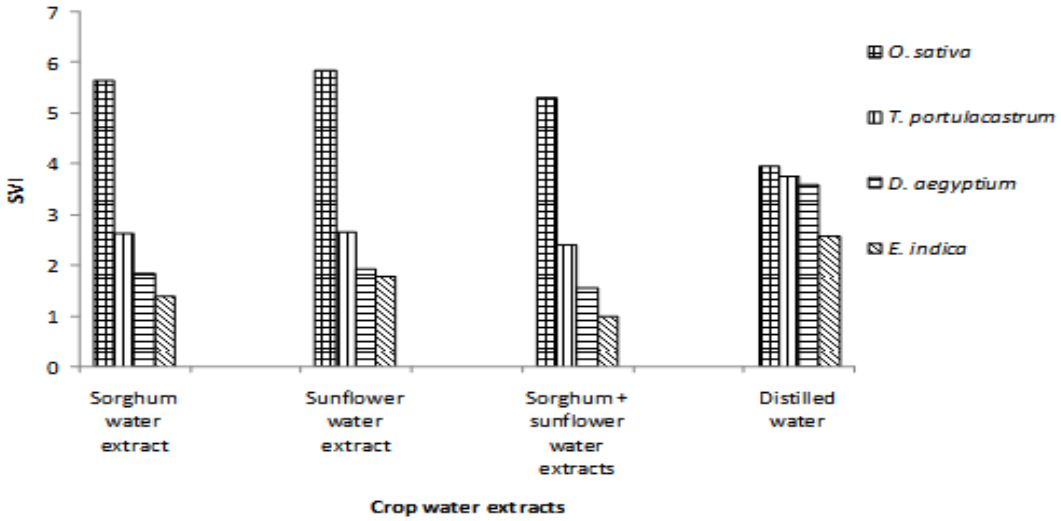

Fig. 4: Effect of water extracts of sorghum and sunflower alone and in combination on Seedling vigor index (SVI) of rice and three weed species.

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