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Allelopathic effects of sunflower water extract integrated with affinity herbicide on weed control and wheat yield

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Abstract. The aim of present study was to investigate the allelopathic impact of sunflower water extract integrated with affinity herbicide on weed management and production of wheat variety TD-1 under field condition. The trial was carried out in a three replicated and the average plot size was kept at 3x5m (15 m^2). The obtained data showed that the all the treatments considerably ($P<0.05$) minimized weed density, weed fresh weight, weed dry weight and weed control up to 90.33, 89.31, 89.61, 90.33% with application of sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) than control treatment. The application of sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) significantly increased number of tillers (32.34%), plant height (14.59%), spike length (27.89%), grains $spike^{-1}$ (16.80%), grain weight $plant^{-1}$ (47%), seed index (19.60%) and grain yield (51%) of wheat as compared with control. Overall results indicated that the sunflower water extract integrated with herbicide can be successfully used to control the narrow and broad leaves in wheat crop.

Key words: allelopathic, sunflower water extract, affinity, agronomic parameters, wheat, productivity.

List of abbreviations and designations: DAS – days after sowing, WP – wettable power, grain weight $plant^{-1}$ – grain weight per plant, grains $spike^{-1}$ – grains per spike, @ – Mean at the rate or application rate.

1. Introduction

Wheat is a staple food crop and contributing over one-third of the globe population. Approximately, 36% population of Pakistan depends on this stable food crop and its total cropping area is occupied 30% as compared to other major crops (Abdul et al., 2012; Li et al., 2022). More than 50% of the agricultural land throughout the country is cultivated with wheat crop during its cropping season (Hussain et al., 2013; Matloob et al., 2020). However, impure seed, irrigation water, wind are the main factors of increasing unwanted weeds cause massive yield losses in wheat and other field crops (Singh et al., 2005; Akbar et al., 2011). On the one side, weed are the main source of animal feed, soil cover, biochar preparation and compost technology, but on the other hand increasing insect population, crop disease and minimize over crop production. In the former practice, the farmers were control weed by using physical, mechanical methods, but these methods were found to time consuming and not applicable for large scale. Since few decades, the application of herbicide had been used at large scale to control unwanted plant from wheat crops (Rashid et al., 2022). The excess application of herbicide for controlling of unwanted weed may cause harm to soil health, water pollution and also affect major crop growth and development (Farooq et al., 2011; Vambol et al., 2020). To tackle this unfriendly approach, the best solution is that to use of organic allelopathy manipulation for crop improvement and ecofriendly safety (Singh et al., 2003). Furthermore, Memon and Bhatti (2003) reported that twenty-four weed species infesting the wheat crop in the wheat fields. Fahad et al. (2015) revealed that the dense population of unwanted weed plants may possibly reduce 30-35% major crop growth parameters and yield, because of dense population unwanted plant include narrow leaf and/or broad leaf may equal share with major crops in water, nutrients, sunlight, density etc. Weeds are responsible for the decline in crop yield losses caused by weeds can be as high as 24% of yield compared with 16.4 and 11.2% for disease and pest, respectively (An et al., 2001). The existing weed control methods are either expensive or hazardous. Sorghum allelopathy for weed management is the safe use of agro-chemicals thus, bioherbicides (allelochemicals) seem to be environment friendly (Naeem et al., 2022). Therefore, alternative strategies against weed must be developed. Allelopathy can be considered as environmental friendly approach for mitigating unwanted weeds and helpful to reduce cost of herbicides and save environmental pollution (Albuquerque et al., 2011). In addition, Bhadoria (2011) stated that the manufacturing of allele-chemicals from several crops biomass has been well known and their potential for weed management. Most of the synthesis herbicides products contents mono or multi toxic chemicals that can be used for control narrow or broad leaves control. The researchers developed some organic herbicides that not only use to control unwanted plants, but also has great importance in environmental protection and socioeconomic point of view. Xuan et al. (2005) reported that the integrated weed management by application of allelopathy could be used as an eco-friendly tool in weed management. Studies have shown an excessive probable of allelopathy for weed management especially in wheat crop (Macias et al., 2007). It can be considered as a best alternative option as compared to synthetic herbicides to control weeds (Naeem et al., 2018). Allelopathy is a phenomenon in which one plant hinders growth of other plants through discharge of allele-chemicals as result due to insufficient food and chemical hang-up (Farooq et al., 2020). Sunflower is recognized to dynamically influence the growth of surrounding plants due to its great allelopathic potential and > 200 natural allelopathic complexes have been isolated from sunflower cultivars. Most of these known allelochemicals affect seed germination (Kamal & Bano, 2008). In Pakistan, many plant species have shown allelopathic influences that could be effectively applied for management of unwanted plant for safe and maximum production (Khan et al., 2011). The negative and positive effects of chemical compounds produced from microorganisms, fungi, viruses and plants manipulate agricultural and biological ecosystems (Martines et al., 2009). The main objectives of this research work were: 1) to examine the allelopathic impact of dissimilar proportion of sunflower water extract on weed management and yield enhancement of wheat; 2) evaluate the effect of studied treatments on narrow leaf and broad leaf herbicides on weed management and yield enhancement of wheat; and 3) find out the most optimum integration of sunflower water extract and herbicides for effective weed management and maximum yield of wheat.

2. Materials and methods

Experimental design: The field experiment was conducted at "Students Farm", Department of Agronomy Sindh Agriculture University Tandojam aiming to evaluate the allelopathic effect of sunflower water extract and herbicides on weed management and yield enhancement of wheat. The map location of study is indicated in (Fig. 1). The seed of wheat variety TD-1 was used throughout the experiment. The experiment was laid out in a three replicated randomized complete block design (RCBD). The net plot size kept was 3x5m (15 m^2). The treatment design and dosage is represented in Table 1.

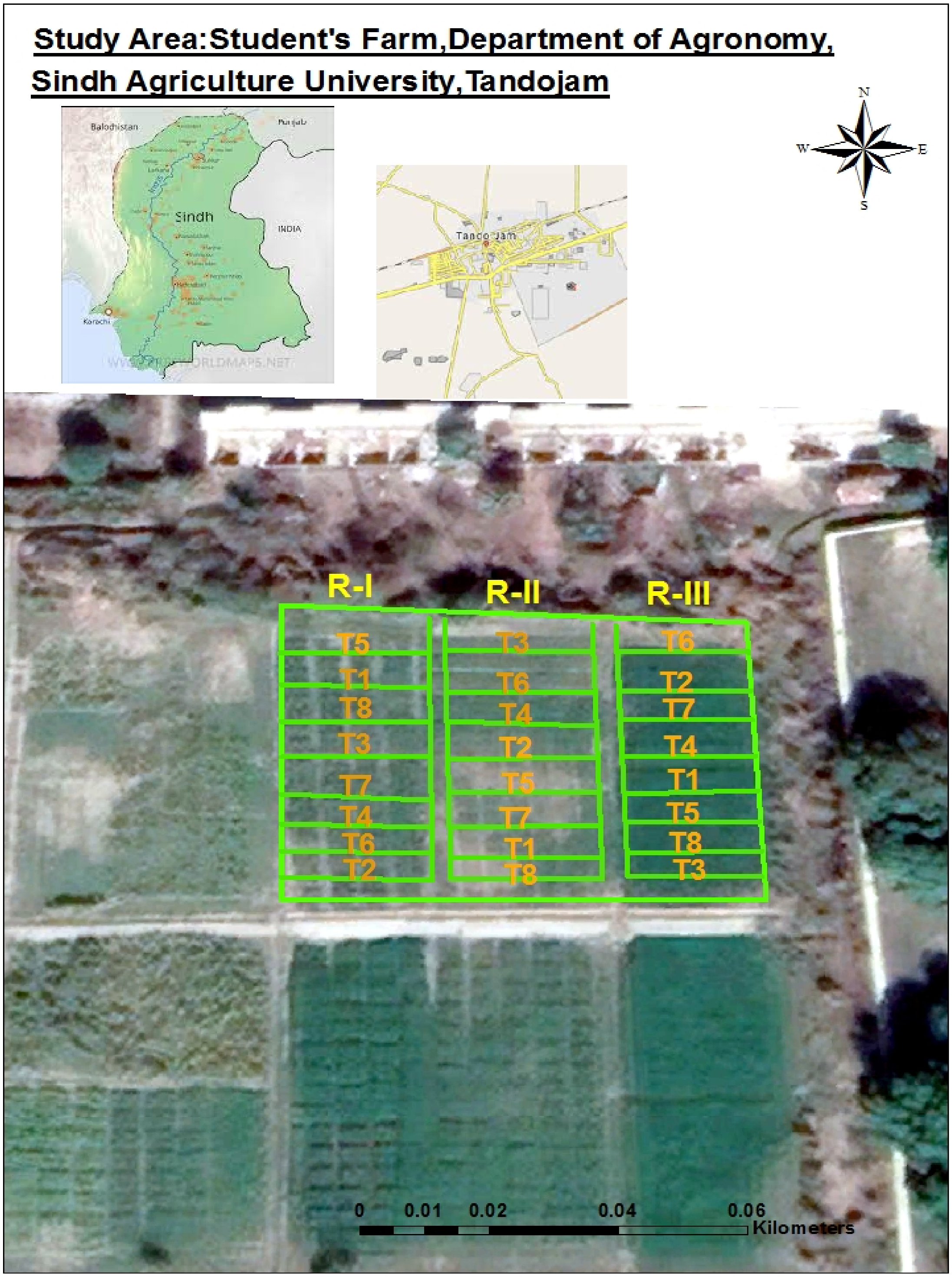

Figure 1. The area in which the research was carried out.

Table 1. Treatment design and dosage of sunflower water extract and herbicides.

Code	Treatments description
T1	Weedy check (Untreated).
T2	Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS).
T3	Sunflower water extract (1:10) @ 20 L ha^{-1} (Two sprays at 25+50 DAS).
T4	Sunflower water extract (1:10) @ 30 L ha^{-1} (One spray at 25 DAS).
T5	Sunflower water extract (1:10) @ 30 L ha^{-1} (Two sprays at 25+50 DAS)
T6	Affinity 50 WP @ 1.5 kg ha^{-1} (One spray at 25 DAS).
T7	Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS)
T8	Sunflower water extract (1:10) @ 30 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS)

Preparation of sunflower water extract

The mature dry plants of sunflower were chopped in small pieces and chopped material was soaked in distilled water for 24 hours at 30°C in a ration of 1:10 (w/v). Furthermore, the extract was filtered by using sieve at finally boiled at 100°C up to 20 minutes.

Application herbicide and sunflower water extract

Except control block the application herbicides and sunflower water extract was sprayed on studied blocks to assess the efficacy of herbicide and sunflower water extract for weed management.

Land preparation: The land was prepared by two dry plowings followed by precision land levelling. After soaking doze, when soil reached proper moisture level, two plowings with cultivator plow were done to achieve the fine seedbed.

Sowing time and method: In the present work, TD-1 variety was chosen and the recommended dose 125 kg ha^{-1} was sown by hand drilling method, and the distance among rows to row was kept at 22.5cm.

Irrigation and fertilizer application: The 1st irrigation was applied to wheat plants 21 days after sowing, 2nd irrigation at ear head formation and 3rd I irrigation was applied at milky stage respectively. The recommended dose of nitrogen 120 kg ha^{-1} in the form of urea was applied with

1st and 2nd irrigation, and phosphorus 75 kg P_2O_5 ha^{-1} in the form of DAP was applied at soil preparation.

Crop harvesting

The matured 3 wheat plants were randomly selected from each plot as per 3 replications. After harvesting ear head/spike was separated from straw during threshing by hand, the studied parameters were measured as per experimental design.

Observations recorded (Weed observations)

Weed flora: In the present study weed density (m^{-2}), weed fresh weight (g m^{-2}), weed dry weight (g m^{-2}), and weed control (%) were measured.

Wheat observations: The number of tillers (m^{-2}), plant height (cm), spike length (cm), grains $spike^{-1}$, grain weight $plant^{-1}$ (g), seed index (1000 grain weight, g), and grain yield (kg ha^{-1}) were measured as per standard way.

Method for recording observations

Weed flora of wheat: All the weed species infesting the experimental area were recorded and their local names, English names, botanical names and families are mentioned in (Table 2).

Table 2. Diversity of weed flora infesting the experimental field of wheat (WFO, 2022).

Local Name	English Name	Botanical Name	Family
		Narrow leaf weeds	
Dumbi siti	Little seed canarygrass	*Phalaris minor* Retz.	*Poaceae*
Jangli javi	Wild oat	*Avena fatua* L.	*Poaceae*
Kabah	Purple nutsedge	*Cyperus rotundus* L.	*Cyperaceae*
Chhabar	Bermuda grass	*Cynodon dactylon* (L.)Pers.	*Poaceae*
		Broadleaf weeds	
Sufaid Sinjh	White sweet clover	*Melilotus alba* Medik.	*Fabaceae*
Peeli Sinjgh	Indian clover	*Melilotus indica* (L.)All.	*Fabaceae*
Jhil	Common Lamb'squarter	*Chenopodium album L.*	*Amaranthaceae*

Chhati kherol	Sunspurge	*Euphorbia helioscopia* L.	*Euphorbiaceae*
Naro	Field Bind weed	*Covolvulas arvensis* L.	*Convolvulaceae*
Jangli palak	Dock	*Rumex dentatus* L.	*Polygonaceae*
Bili booti	Blue pimpernel	*Anagallis arvensis* L.	*Primulaceae*

Weed density (m^{-2}): The weeds were counted at 60 DAS by using wooden frame of one square meter in all plots of each treatment at one location and calculated as (m^{-2}). The following formula was applied:

$$\text{Weed density } (m^{-2}) = \frac{\text{Total number of weeds for given treatment}}{\text{Number of replications}} \quad (1)$$

Weed control (%): Weed control (%) was calculated by using the following formula.

$$\text{Weed control } (\%) = \frac{\text{Weedy Check density - Given treatment density}}{\text{Weedy Check density}} \cdot 100 \quad (2)$$

Weed fresh weight (g m^{-2}): Weeds fresh weight was taken from randomly selected areas of one-meter square at one stage at 60 DAS and recording the fresh weight.

Weed dry weight (g m^{-2}): weeds dry weight the samples taken for fresh weight were dried at 70°C for 72 hours.

Number of tillers (m^{-2}): Total tillers (m^{-2}) in each plot from three different locations was counted at the time of maturity and averaged.

Plant height (cm): Plant height was recorded at maturity of the crop in randomly selected three plants using measuring tape from bottom to tip of the spike in centimetres.

Spike length (cm): The length of all the spikes in randomly selected plants will be measured in centimetres with measuring tape and average will be worked out.

Number of grains spike^{-1}: The number of grains in each spike of the randomly selected plants was counted at the crop maturity and average will be worked out.

Grain weight plant^{-1} (g): The all spikes of the plant were threshed and measured the yield in grams through electric weight balance in laboratory.

Seed index (1000 grain weight, g): For recording seed index value, 1000 grains from all the randomly selected plants in each plot was collected at random and weighed in grams.

Grain yield (kg ha^{-1}): The grain yield (kg ha^{-1}) was calculated by using the following formula.

$$\text{Grain yield}\,(\text{kg}\cdot\text{ha}^{-1}) = \frac{\text{Grain yield plot}^{-1}\,(\text{kg})\cdot 10000}{\text{Area of plot}\,(\text{m}^2)} \tag{3}$$

Geospatial techniques

Geospatial techniques are notable in the ex-situ condition for managing, monitoring the huge data set easily and resourcefully. In the present work, high-resolution satellite imaginary data have been extracted from Google earth then geo-referencing techniques have been used for image restructuring. For extraction of the area of interest, a mask tool has been used. The editor tool has been used for the digitization of image data.

Statistical analysis

The obtained data was subjected to ANOVA techniqne using MSTAT-C computer software. The LSD test was applied to compare treatment means superiroity, where necessary. All graphs were prepared by using Origin Pro. 16. The pearson correlation coefficients between weed density, weed fresh weight, weed dry weight, weed control, tillers, plant height, spike length, and grains per spike, grain weight, seed index and grain yield were also performed using IBM SPSS Statistics for Windows, Version 21.0.

3. Results and discussion

As shown in (Fig. 2a) the obtained results revealed that the all experimental treatments were found to be highly effective to reduce the weed density (m^{-2}) as compared to control treatment. While, the maximum reduction of weed density was 90.33% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS), rather than control treatment. Furthermore, the greatest weed fresh weight (g m^{-2}) was observed by 89.31% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS), as compared to control treatment (Fig. 2b). As compared the control, the weed dry weight (g m^{-2}) was evidently reduced up to 89.61% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) (Fig. 2c). The maximum weed control (%) was found to be 90.33% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) rather than control treatment (Fig. 2d). Above results indicated the application of different concentrations of sunflower water extract and herbicide have highly potential to reduce weed density, weed fresh weight, weed dry weight, and weed control in wheat crop. Indeed, allelopathy is an environment friendly technique in controlling weeds and helpful in reducing cost of herbicide. Furthermore, allelopathic plants may also be considered a potential source of new molecules with herbicidal action for the chemical industry, the necessity of which is due to the emergence of resistant weeds to older synthetic molecules. Moreover, allelopathic potential in crop plants can be successfully utilized for weed management. Certain crops restrain growth of some weed species while phytotoxins releasing from their residues inhibit seed germination of weeds. Indeed, allele-chemicals from several crops have been identified and their activity for weed management has also been established (Bhadoria, 2011). Research in allelopathy focuses on isolating, identifying and quantifying specific active allelochemicals. Once these substances are identified and characterized they can be used either as natural herbicides or as models for developing new and environment friendly herbicides. Studies have shown a great potential of allelopathy for weeds control in wheat. It is the best alternatives to the synthetic herbicides to control weeds (Bhowmik & Inderjit, 2003; Jabran et al., 2008).These outcomes are supported by Naeem et al. (2016), who stated that the lessening in weed dry weight with sorghum and sunflower extracts by foliar spraying.

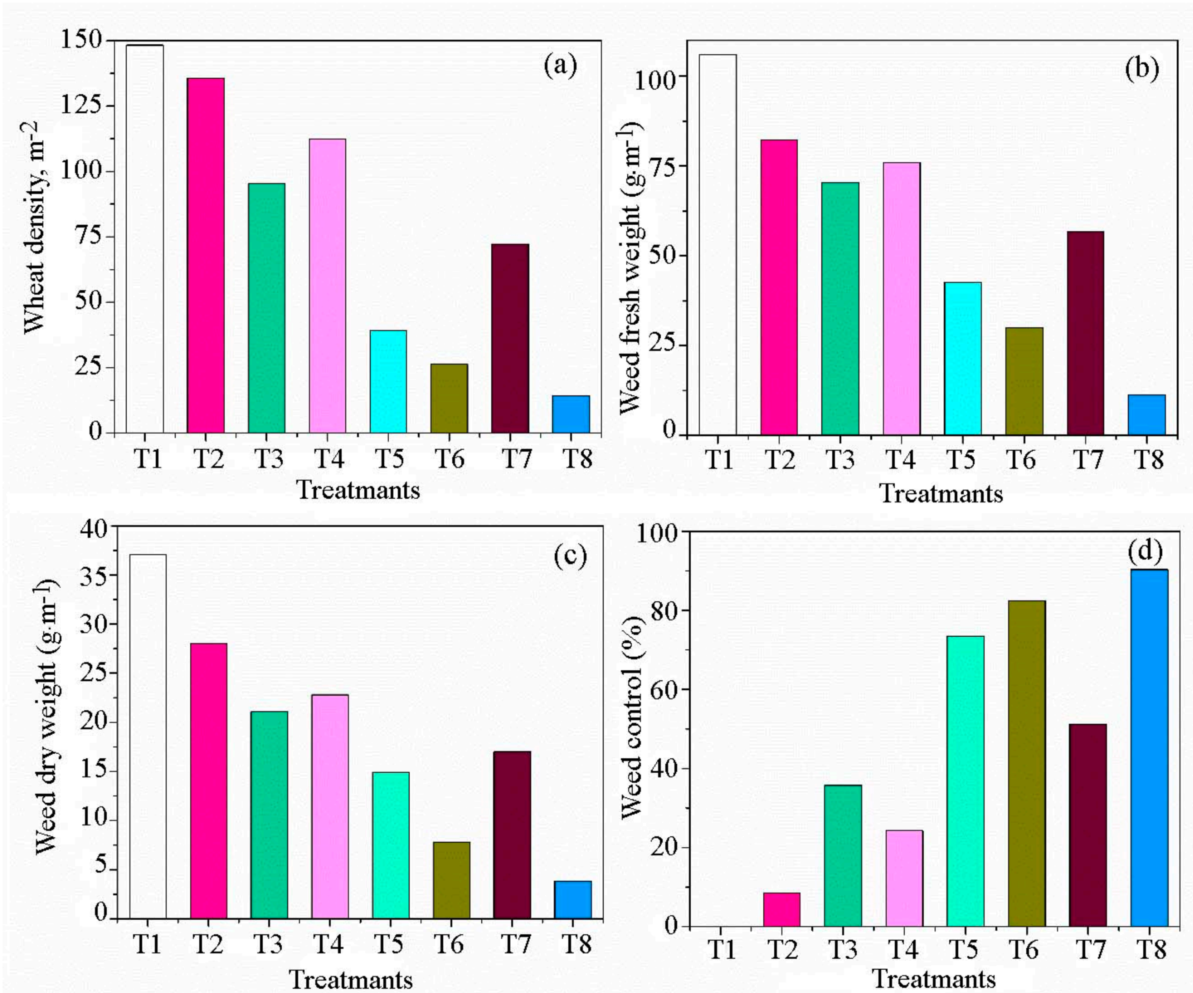

Figure 2. Weed density (a), weed fresh weight (b), weed dry weight (c), and weed control (d) as affected by allelopathic effect of sunflower water extract and herbicides in wheat.

The obtained experimental data in showed that the studied treatments evidently increased the number of tillers, plant height, spike length, and grains per spike of wheat plant as compared to control treatment. The maximum tillers (m^{-2}) of wheat was received by 32.34% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) rather than control treatment (Fig. 3a). Furthermore, the greatest plant height (cm) of wheat was 14.59% with Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) as compared to control treatment (Fig. 3b). Similarly, the highest Spike length (cm) of wheat crop was noted 27.89% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) than control (Fig. 3c). Also, the maximum grains $spike^{-1}$ of wheat was 16.80% with application of Sunflower water extract

(1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) as compared with control treatment (Fig. 3d).The results of present experiment showed that all the levels of sunflower water extract caused significant inhibition on weed management and yield enhancement of wheat. Yields of some crops following sunflower are lower than normal, possibly because of inadequate nutrition and chemical inhibition. Sunflower is often grown when rainfall is marginal and depletion of soil moisture by sunflower may be a factor, although, this remains unproven (Kamal & Bano, 2008).

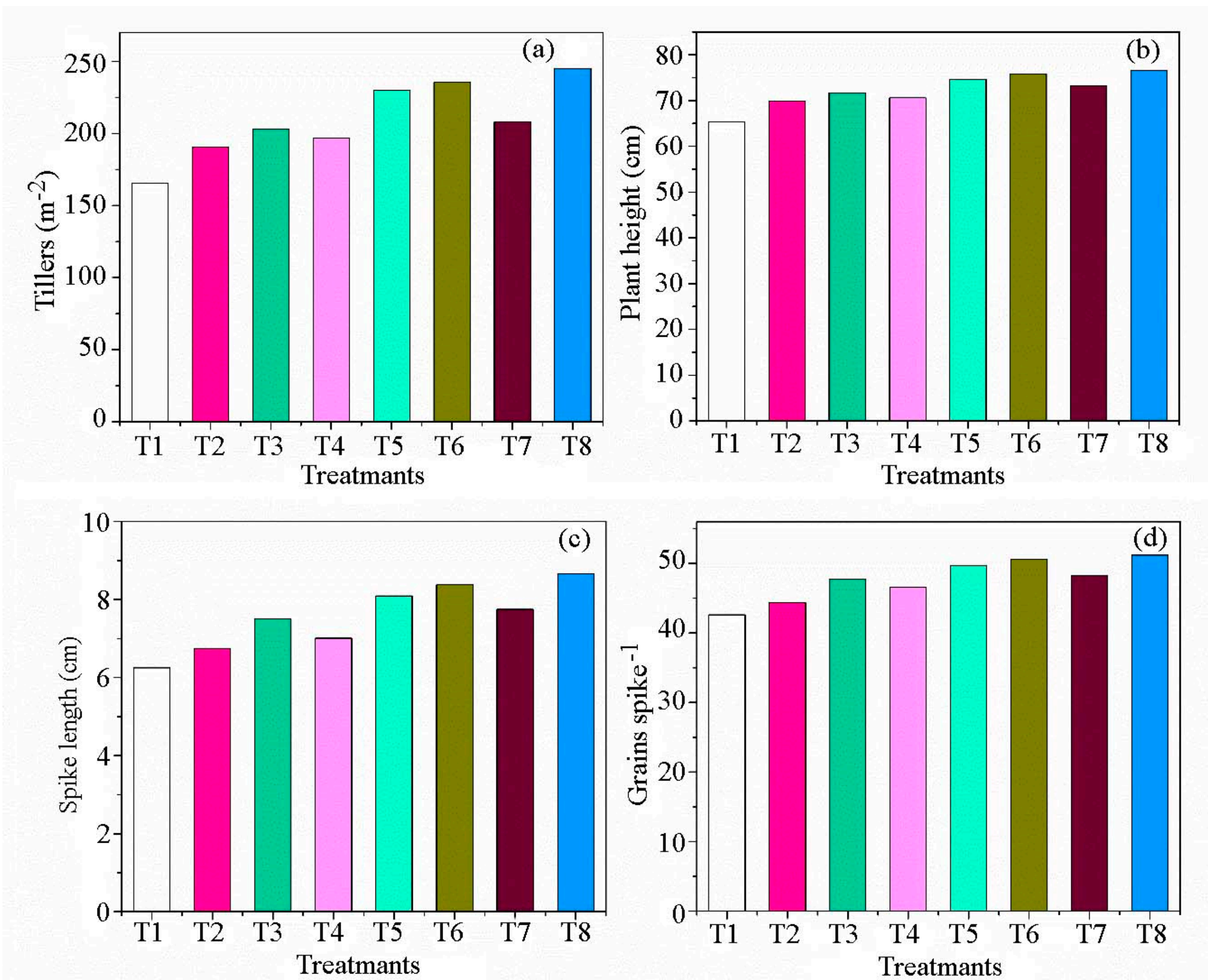

Figure 3. Tillers (a), plant height (b), spike length (c), and grains per spike (d) as affected by allelopathic effect of sunflower water extract and herbicides in wheat.

The experiment results revealed that the grain weight per plant, seed index and grain yield of wheat crop was potentially increased with application of different concentrations of sunflower water extract and herbicide. The maximum grain weight plant^{-1} (g), seed index 1000 grain weight

(g) and grain yield (kg ha^{-1}) was recorded up to 47%, 19.60% and 51% with application of Sunflower water extract (1:10) @ 20 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} (One spray at 25 DAS) than control treatment (Fig. 4a, b, c). The effectiveness of bioherbicide depends on many factors as soil type,moisture content,organic matter, prevailing temperature, etc., (Matloob et al., 2015). Our results are in line with Naeem et al. (2018), who observed that the yield of wheat was significantly increased and weeds were reduced with application of sorghum, sunflower and mulberry extract. Appropriate weed controlling is likely to raise wheat yield by more than one million ton in Pakistan (Marwat et al., 2011).

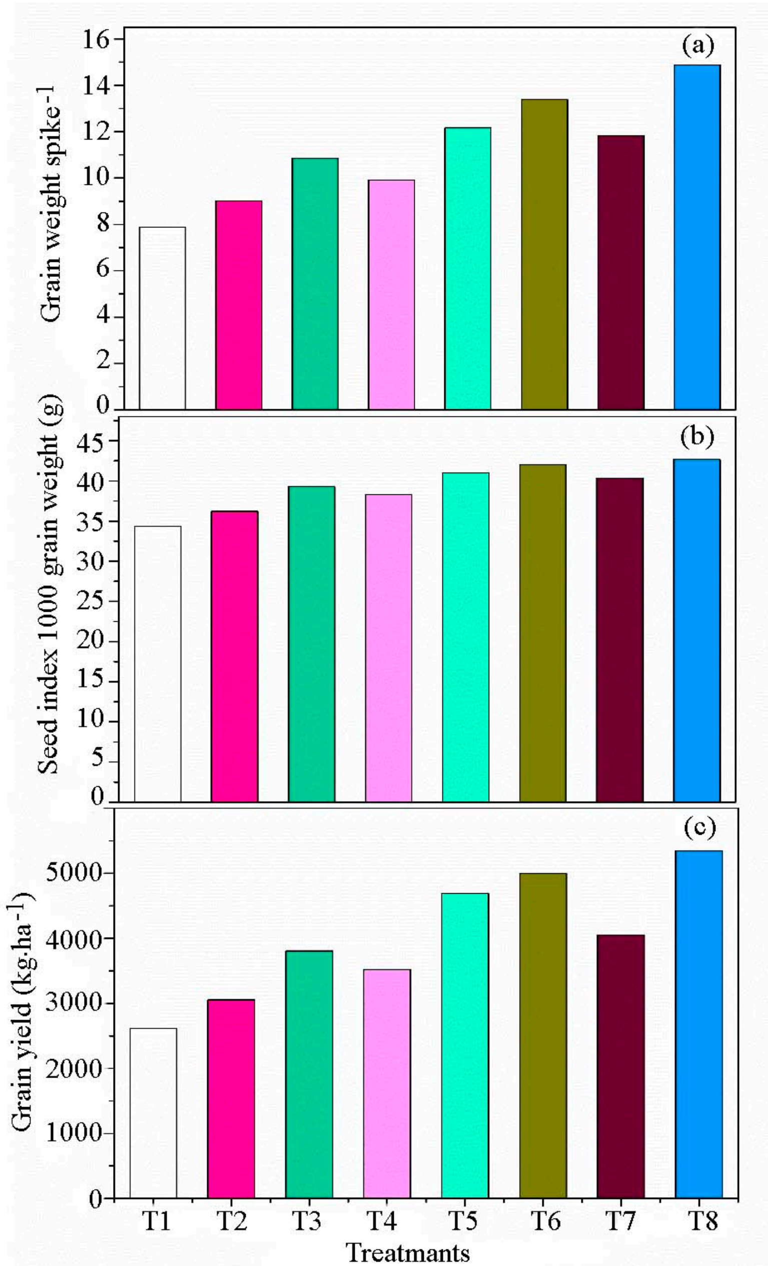

Figure 4. Grain weight (a), seed index (b), and grain yield (c) as affected by allelopathic effect of sunflower water extract and herbicides in wheat.

Pearson correlation analysis

Pearson correlation analysis was performed to assess the relationship between different weed density, weed fresh weight, weed dry weight, weed control, tillers, plant height, spike length, and grains per spike, grain weight, seed index and grain yield (Table 3). The weed fresh weight had highly significant correlation with weed density.

Table 3. Pearson correlation coefficient between studied parameters.

Traits	WD	WFW	WDW	WC	T	PH	SL	GS	GW	SI	GY
WD	1										
WFD	.977**	1									
WDW	.966**	.988**	1								
WC	-1.00**	-.977**	-.966**	1							
T	-.977**	-.988**	-.982**	.977**	1						
PH	-.956**	-.973**	-.983**	.956**	.985**	1					
SL	-.989**	-.983**	-.984**	.989**	.983**	.980**	1				
GS	-.975**	-.962**	-.980**	.975**	.976**	.978**	.988**	1			
GW	-.977**	-.990**	-.988**	.977**	.970**	.962**	.989**	.970**	1		
SI	-.969**	-.961**	-.983**	.969**	.968**	.981**	.987**	.997**	.972**	1	
GY	-.995**	-.989**	-.983**	.994**	.990**	.969**	.993**	.983**	.986**	.976**	1

Note: Correlation is significant at **p<0.01; **WD** = weed density; **WFW** = weed fresh weight; **WDW**= weed dry weight; **WC**= weed control; **T**= tillers; **PH**= plant height; **SL**= spike length; **GS**= grains spike^{-1}; **GW**= grain weight; **SI**= seed index and **GY**= grain yield.

The weed dry weight was highly significant correlation with weed density and weed fresh weight. Weed control had negatively highly significant correlation with weed density, weed fresh weight and weed dry weight. Tillers were negatively correlated with weed density, weed fresh weight, weed dry weight, but positive correlation with weed control. Plant height had negative correlation with weed density, weed fresh weight, weed dry weight, but positive correlation with weed control and tillers. Spike length had negative correlation with weed density, weed fresh weight, weed dry weight, but positive correlation with weed control, tillers and plant height. Grains per spike were negatively correlated with weed density, weed fresh weight, weed dry weight, whereas positive correlation with weed control, tillers, plant height and spike length. Grain weight found to be negative correlated with weed density, weed fresh weight, weed dry weight, however positive correlation with weed control, tillers, plant height, spike length and grains spike^{-1}. Seed index was negatively correlated with weed density, weed fresh weight, weed dry weight, but positively correlated with weed control, tillers, plant height, spike length, grains spike^{-1}and grain weight. Grain yield had positive correlation with weed density, weed fresh weight, weed dry weight, but positively correlated with weed control, tillers, plant height, spike length, grains spike^{-1}, grain weight and seed index.

4. Conclusions

The results concluded that the combination of sunflower water extract (1:10) @ 30 L ha^{-1} (One spray at 25 DAS) + Affinity 50 WP @ 0.75 kg ha^{-1} soil was found highly allelopathic and resulted in lowest growth and related traits of wheat. However, allelopathic potential of this weed could be exploited as effective, cheap and eco-friendly strategy for weed management. In future, long-term ex-situ studied are needed to understand the mechanism underlying soil health, microbial biomass, soil enzymatic activity, physiology of crop, crop production and weed management under. Furthermore, the herbicides contaminated plants can be convert for energy purpose and to made smart biochar as soil amendment for waste management and environmental clean-up.

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