Shoaib Anwar Kohli, Saeed Rauf*, Muhammad Waqas Khalid, Wardah Kainat, Jakub Paderweski, Hassan Munir, Ali Hassan, Ijaz Rasool Noorka and Imtiaz Akram Khan Niazi

Competitive ability of sunflower (*Helianthus annuus* L.) breeding material under *Cyperus rotundus* infestation

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Abstract: Weed infestation induces intense competition with the sunflower crop for soil nutrients, space and light causing significant yield losses of the sunflower. Therefore, study was undertaken during the year 2013–15 at College of Agriculture, University of Sargodha, Pakistan to determine the effect of *Cyperus rotundus* infestation on various morphological and biochemical traits. Initially a screening experiment was carried out to screen against *C. rotundus* infestation. Later on, cross combinations of selected cytoplasmic male sterile and restorer lines were attempted to develop F_1 progenies which were compared with commercial hybrids along with parents. There were 6 parental lines (3 A and 3 R lines) along with 9 single cross combinations obtained from these parents. Experiment was carried out in complete randomized design having factorial arrangement with three replications. Weed in one of regime latter called as control were completely absent, while in weed infestation regimes 5 and 10 plants of *C. rotundus* were maintained. Results showed that *C. rotundus* infestation causes significant damage to the sunflower plants. Generally cross combination showed a decrease of leaf area by 440% and 264%, 61% and 49% for chlorophyll contents, 133% and 191% for head

***Corresponding author: Saeed Rauf**, Department of Plant Breeding & Genetics, College of Agriculture, University of Sargodha, Sargodha, Pakistan; and Plant Tissue Culture Laboratory, College of Agriculture, University of Sargodha, Sargodha, Pakistan,
E-mail: saeedbreeder@hotmail.com
Shoaib Anwar Kohli and Imtiaz Akram Khan Niazi, Fodder Research Institute, Sargodha, Pakistan
Muhammad Waqas Khalid and Wardah Kainat, Department of Plant Breeding & Genetics, College of Agriculture, University of Sargodha, Sargodha, Pakistan
Jakub Paderweski, Department of Experimental Design and Bioinformatics, Warsaw University of Life Sciences, Nowursynowska 159, Warsaw 02-776, Poland
Hassan Munir, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
Ali Hassan, Oilseed Research Institute, Bhawalpur, Pakistan
Ijaz Rasool Noorka, Department of Plant Breeding & Genetics, Ghazi University, Dera Ghazi Khan, Pakistan

weight under low and high weed infestation regime respectively. However, antioxidant activity increased by 44% and 49% under low and high infestation regime induced by *C. rotundus*. Sunflower genotypes also showed variability in competitive ability against *C. rotundus* weed. Cross combinations coded as (A10, A7 and A2) showed lower comparative decrease for seed yield and oil contents when compared with standard hybrids under the presence of *C. rotundus*. Development of sunflower hybrids with better competitive ability under the presence of weeds such as *C. rotundus* may able to enhance plant development and lower yield losses in sunflower field with minimum the use of herbicide.

Keywords: allelopathy; competition; herbicide; infestation; oil contents.

Introduction

Sunflower yield was threatened by various factors including biotic and abiotic (Rauf 2019). Among biotic factors, weeds were hidden foe of crop plant which may cause substantial losses (40–70%) in sunflower crop (da Silva Alcântara et al. 2019). Yield losses were estimated to be higher than any other pests of crops (Jabran et al. 2015). High weed infestation can cause complete crop failure or deteriorated quality of crop produce under un-checked weedy growth (Das et al. 2012). However, losses were dependent upon crop and weed. Among various weeds, *Cyperus rotundus* is a common short statured weed. The weed was known to compete with sunflower during all crop seasons and its control through agronomic and chemical method was found difficult due to very high regeneration capacity. It caused substantial losses by reducing germination and increased seedling mortality of many crops during crop establishment phase (Peerzada 2017). It affects the crop plants by several factors such as release growth retardants, takes away part of soil nutrient and moisture content, compete for light and space during crop establishment (Peerzada 2017).

Different weed control methods used in crops include physical, chemical, biological and ecological each having its own relative advantages and limitations. The chemical control has been widely used against weed infestation due to difficulties in management involved in physical and biological methods. Indiscriminate use of herbicides, however, involved ecological and health issues like herbicide resistance development in weeds, environmental pollution and effects on nontarget organisms (Bajwa et al. 2017). The biological weed management may also be a viable approach but its cost-intensiveness and certain ecological risks (Pemberton 2000) has made it unsuitable. These concerns have brought attention of weed scientists across the world to develop ecological weed management strategies (Chauhan and Johnson 2010; Mortensen et al. 2000). In addition to its environmental benefits, ecological weed management does not involve any additional cost and it also gave long-term weed control (Chauhan and Gill 2014). Accelerated research on weed competitive crop leads to the more economical effective feasible program to control the weed (Bajwa et al. 2017). The identification and adaptation of weed-competitive crop genotypes with somewhat allelopathic potential could be a successful ecological weed management approach that can help growers in minimizing herbicide use without compromising crop yield (Mahajan and Chauhan 2013). Screening trials under target condition may help to screen inbred lines and subsequently hybrids which show good response and could provide comparable yields under high weed infestation conditions.

On the basis of these facts, study was conducted with the following objectives to identify parental and hybrid combinations of sunflower that were competitive to weed infestation and to estimate losses on the basis of morpho-biochemical traits under simulated weed infestation regimes. Allelopathic effects of sunflower plant over weed growth and sunflower resistance against herbicides.

Materials and methods

The studies were carried out in department of Plant Breeding and Genetics and Plant Tissue Culture laboratory, College of Agriculture, University of Sargodha, Pakistan during 2013–2015.

Experiment 1

Collection of germplasm: Sunflower germplasm was obtained from an on-going project. Breeding lines were screened for their resistance to weed infestation. There were 6 material parental lines which included: cytoplasmic male sterile (CMS) (A6, A7, A9) and restorer lines (R5, R8-1 and R26). Selected material was intermated to yield 9 cross combinations during year 2013 (Table 1).

Table 1: List of parents and their obtained progenies along with commercial hybrids (Hysun33 and S278) used in the experiment.

Female	Male	Code	Cross combination	Code	Cross combination
B6	R5	C1	A14 × R-8-1	C6	A9 × R-26
B7	R8-1	C2	A24 × R-8-1	C7	A7 × R-26
B9	R26	C3	A9 × R-5	C8	A24 × R-26
B14		C4	A7 × R-5	C9	A14 × R-26
B24		C5	A9 × R-8-1	C10	A6 × R-26

Experimental conditions: Commercial hybrids i.e. Hysun33 and S278 were sown in plastic pots (14 cm depth × 12 cm diameter) filled with equal volume of field soil (loam), sand and silt loam. Fertility of soil was improved by adding 3% of organic matter obtained from well-rotted farm yard manure and 2 g of diammonium phosphate. Experiment was carried out in completely randomized design having factorial arrangement with three replications. There were ten plants within each replication. Temperature was maintained at 25 ± 2 °C with photoperiod length of 16 h and relative humidity of 40%. Photon flux density was 650 μmol m^{-1} s^{-1} induced through artificial light source from filament bulb. Investigated factors included various genotypes and three weed infestation regimes. Two weed infestation levels (5 and 10 plants pot^{-1}) of *C. rotundus* weeds were employed by contaminating the soil with weed seeds (50 seeds pot^{-1}) while in no weed infestation regime (control), soil was kept weed free. The pots were regularly irrigated to allow the germination of the weeds in the pots and to achieve desired weed density in each pot, surplus weed seedlings at their 5 cm shoot length were uprooted. Two seeds of each sunflower genotype (Table 1) were sown after the establishment of weed regimes within pots. The purpose of this treatment was to discriminate sunflower germplasm during germination and seedling establishment against intense weed competition. Previous study has also showed that sunflower seedlings showed the highest susceptibility during germination and seedling growth (Lewis and Gulden 2014). All pots were irrigated to field capacity (16% by weight) to avoid any water stress.

Field trial: Weed infestation resistant hybrids (C3, C6, C8, C9, C10) chosen from initial screening trials, along with two check hybrids Hysun33 (ICI, Pakistan) and S278 (Syngenta, Pakistan) were evaluated during the year 2015–16. The experiment was carried out on sandy loam soil having EC=2.92 ± 0.21; pH=7.61 ± 0.19; available potassium 193 ± 7.12, and available phosphorous 18.12 ± 4.62. Experiment was laid out in split plot design with weeds in main plots and hybrids in sub plots. There were two main plots i.e. with weed control and without weed control. The weeds in control main plot were controlled through pre-mergence spray of herbicide "S-metolachlor" (Dual gold Magnum, Syngenta) and later on controlled through manual hoeing to keep weeds under check, while weed infestation main plot was kept weedy with no weed control having high weed intensity. The seed of hybrids were sown in both plots on 24 February, 2015 and 21 February, 2016 at plant to plant distance of 30 cm while row to row distance was 100 cm. Each hybrid was sown in three rows within each replication. The size of sub plot was about 1.5 × 6 m. There were three replications. The plants were irrigated with canal water during the entire growing season. The soil fertility was raised by adding 95 kg ha^{-1} of diammonium phosphate at the time of sowing in both plots while urea was added in two splits (30 days post emergence and 55 days post emergence) at the rate of 130 kg ha^{-1}. The plant protection measures were practiced by applying lufenuron (Match® Syngenta) at 200 mL ha^{-1} during anthesis (60 days after emergence).

Morphological traits: The plants were evaluated for the following traits at the time of anthesis and physiological maturity.

Grain yield was recorded by harvesting heads manually from 10 plants from middle row for each hybrid and then manually threshed. The grains were dried to 14% moisture level and then grain yield $head^{-1}$ was determined by digital balance.

Oil contents were measured by petroleum ether extraction method through Soxhlet apparatus. Crushed seed sample of 10 g was put in thimble within extractor until all the oil within sample was recovered. The oil % was determined by following equation:

$$\text{Oil contents \%} = \frac{(\text{Total seed mass} - \text{seed mass recovered after oil extraction}) \times 100}{(\text{Total seed mass})}$$

Leaf area was measured by using manual scanned leaf area meter (CI-202, Camas, USA). Leaves (15 days old) were tagged at the top of the canopy and detached from leaf petiole appearance to determine leaf area. Chlorophyll contents were measured by chlorophyll meter (CL-01, Chlorophyll meter, Hansatech instruments, UK). 15 days old leaf was used to determine the differences among the genotypes for chlorophyll contents. Head (capitula) of all the plants was harvested and incubated at 60 °C for constant biomass. The head biomass was measured on digital balance.

Antioxidant activity: Sunflower leaves of similar age were collected at the time of anthesis to analyze antioxidant activity at Department of Agronomy, University of Agriculture, Faisalabad. Samples of 0.25 g were chopped and were extracted in 80% methanol for 16 h at room temperature. Afterwards, the extracts were centrifuged at 9000 rpm for 10 min. Supernatants were extracted by using glass pipette. Antioxidant activity in extracts was determined using the DPPH radical-scavenging method with modification in the extract. A 400 micro molar of DPPH (2,2-Diphenyl-l-picrylhydrazyl) solution was prepared in 80% methanol and was equally mixed with leaf extract. The mixed solution was incubated for 30 min in darkness at room temperature. The absorbance was measured by spectrophotometer at 518 nm (UV-2600, Shimadzu, Kyoto, Japan) using 80% methanol as blank. Similarly, absorbance of samples was also measured after mixing equal volume of samples with equal volume of 80% methanol. Free radical-scavenging activity (%) was calculated using following equation:

$$\text{Radical} - \text{scavenging activity} = (B - A) \times 100/B$$

where A is the absorbance of [(sample + DPPH) – (sample + methanol)] and B is the absorbance of [(methanol + DPPH) – (methanol)]. The IC_{50} value, which is the concentration required to obtain 50% antioxidant capacity, was calculated and was used to compare the antioxidant activities of sample extracts (Bhandari and Kwak 2015).

Biometrical and statistical analysis: All the traits were analyzed by the analysis of variance method in completely randomized design in factorial arrangement. There were two factors i.e. genotypes and treatments (differential weed regime). Traits in field trials were determined in split : split plot arrangement with three factors i.e. hybrids, weed regimes and years.

Results

Analysis of variance showed significant ($p \leq 0.05$) variation due to genotypes and genotypes × treatments (weed infestation regime) for all traits under study (Table S1). Significant interaction suggested the differential ranking of genotypes across weed infestation regime.

Impact of weed infestation on morpho-biochemical traits

Weed infestation reduced leaf area by 440% and 264% in cross combinations under high and low weed infestation regimes, respectively (Figure 1; Table 2). In Parents, weed infestation reduced leaf area by 764% and 427% in high and low regime, respectively. Tukeys test was applied to distribute genotypes into various homogeneity groups. Among parents, restorer R-8-1 followed by maintainer lines B7 and B6 was promising under control and infestation regimes (Table 2). Hybrids C6, C10 and C3 may be considered promising in control and weed infestation regimes (Table 2). These hybrids may be considered promising due to their overall performance under all treatments.

(a)
(b)


Figure 1: A view of three treatments control, low weed infestation regime (5 weeds per pot) and high weed infestation regime (10 weeds per pot) from left to right for (a) C7 resistant progeny (A7 × R26) and (b) susceptible commercial hybrid Hysun-33.

Table 2: Mean values of leaf area (cm^2) as affected by the contrasting weed regimes and chemical control of weeds (*Cyperus rotundus*) in sunflower (*Helianthus annuus* L.).

Genotype	Weeds infestation regime			Chemical spray
	Control	5	10	
Parents				
B6	68.48 ± 4.02	11.81 ± 2.12	4.31 ± 2.90	
B7	42.28 ± 3.89	16.89 ± 2.02	17.68 ± 1.69	
B9	31.23 ± 1.69	12.36 ± 2.74	9.35 ± 3.15	
R5	81.55 ± 7.19	7.87 ± 1.60	3.51 ± 0.72	
R8-1	55.72 ± 8.01	11.46 ± 2.28	9.06 ± 1.70	
R26	94.01 ± 12.21	23.46 ± 1.61	19.75 ± 0.35	61.42 ± 1.27
Average	69.61^b	16.30^a	8.06^b	61.42
F_1Crosses				
A14 × R-8-1	39.36 ± 2.89	15.23 ± 1.17	7.57 ± 3.19	
A24 × R-8-1	54.67 ± 3.51	8.87 ± 0.46	8.77 ± 1.69	
A9 × R5	50.21 ± 5.46	22.34 ± 3.61	23.75 ± 6.05	
A7 × R5	48.20 ± 6.00	7.16 ± 1.89	7.64 ± 1.18	
A9 × R-8-1	51.81 ± 4.32	12.13 ± 0.97	11.20 ± 2.15	
A9 × R26	55.31 ± 9.56	27.10 ± 1.54	24.58 ± 3.52	67.43 ± 6.12
A7 × R26	34.39 ± 11.32	36.12 ± 1.42	37.36 ± 4.10	54.26 ± 7.56
A24 × R26	54.05 ± 8.71	13.94 ± 1.02	8.36 ± 2.37	
A14 × R26	89.43 ± 6.84	14.40 ± 0.65	16.14 ± 2.23	51.00 ± 2.08
A6 × R26	62.33 ± 10.60	39.14 ± 2.01	12.95 ± 2.51	52.17 ± 4.19
Average	53.98^c	17.64^a	14.83^a	56.22
Commercial hybrids				
Hysun33	85.86^a ± 5.74	6.36^b ± 1.91	8.13^b ± 1.79	
S278	64.67^b ± 8.74	6.26^b ± 1.14	4.13^c ± 1.43	

[abc]Means within a column followed by different letters are significantly (p≤0.05).

Overall there was an increase of 49% and 44% under high and low weed infestation regimes, respectively, in cross combination for antioxidant activity (Table 3). Among parents, antioxidant value increased by 36% and 43% under high and low weed infestation regimes, respectively. Parent R5, R26 and B-7 showed the highest antioxidant value under control and weed infestation regimes. Hybrids such as C9, C10, C6 and C5 were promising with respect to antioxidant value (Table 3).

Chlorophyll contents decreased by 61% and 49% in cross combinations under high and low infestation regimes, respectively (Table 4). Overall, parents showed a decrease of 50% and 21% for chlorophyll contents in high and low weed infestation

Table 3: Mean values of antioxidant (absorbance) as affected by the contrasting weed regimes and chemical control of weeds (*Cyperus rotundus*) in sunflower (*Helianthus annuus* L.).

Genotype	Weeds infestation regime			Chemical spray
	Control	5	10	
Parents				
B6	0.41 ± 0.03	0.58 ± 0.04	0.60 ± 0.03	
B7	0.53 ± 0.03	0.59 ± 0.05	0.56 ± 0.08	
B9	0.36 ± 0.02	0.53 ± 0.03	0.41 ± 0.03	
R5	0.39 ± 0.04	0.61 ± 0.04	0.71 ± 0.03	
R8-1	0.26 ± 0.08	0.65 ± 0.04	0.30 ± 0.03	
R26	0.48 ± 0.03	0.55 ± 0.03	0.68 ± 0.03	0.74 ± 0.05
Average	0.42^{a}	0.60^{a}	0.57^{b}	0.74
F_1 Crosses				
A14 × R-8-1	0.40 ± 0.06	0.61 ± 0.03	0.52 ± 0.16	
A24 × R-8-1	0.32 ± 0.03	0.59 ± 0.03	0.70 ± 0.03	
A9 × R5	0.46 ± 0.04	0.60 ± 0.07	0.41 ± 0.02	
A7 × R5	0.41 ± 0.02	0.62 ± 0.04	0.48 ± 0.04	
A9 × R-8-1	0.43 ± 0.04	0.62 ± 0.08	0.75 ± 0.04	
A9 × R26	0.41 ± 0.03	0.71 ± 0.03	0.68 ± 0.03	0.52 ± 0.04
A7 × R26	0.38 ± 0.01	0.56 ± 0.02	0.58 ± 0.03	0.76 ± 0.07
A24 × R26	0.48 ± 0.06	0.54 ± 0.02	0.67 ± 0.03	
A14 × R26	0.62 ± 0.02	0.66 ± 0.02	0.78 ± 0.05	0.58 ± 0.04
A6 × R26	0.42 ± 0.04	0.73 ± 0.05	0.86 ± 0.03	0.67 ± 0.03
Average	0.43^{a}	0.62^{a}	0.64^{ab}	0.63
Commercial hybrids				
Hysun-33	0.31^{bc} ± 0.03	0.59^{a} ± 0.12	0.67^{a} ± 0.03	
S78	0.35^{c} ± 0.03	0.64^{a} ± 0.04	0.64^{ab} ± 0.03	

[abc]Means within a column followed by different letters are significantly (p≤0.05).

regimes, respectively. Hybrid C-10 was ranked 1 for chlorophyll contents across all regimes. Among parent B-6, R-8-1 and B-7 showed better performance across all regimes (Table 4).

Weed infestation regimes reduced the sunflower head weight by 133% and 191% in low and high weed density regime in comparison with control. Parents B-7 showed promising value under low and high weed infestation regime. Hybrids such as C8, C6 and C3 were ranked better for overall performance (Table 5). Overall averages of cross combinations were significantly (p≤0.05) higher than both commercial hybrids in weed infestation regimes (Table 5).

Table 4: Mean values of chlorophyll content as affected by the contrasting weed regimes and chemical control of weeds (*Cyperus rotundus*) in sunflower (*Helianthus annuus* L.).

Genotype	Weeds infestation regime			Chemical spray
	Control	5	10	
Parents				
B6	8.21 ± 1.02	6.29 ± 1.17	3.43 ± 0.61	
B7	5.35 ± 0.73	5.45 ± 0.97	6.95 ± 1.29	
B-9	4.12 ± 1.01	5.37 ± 0.59	3.98 ± 0.64	
R5	4.50 ± 0.70	3.28 ± 0.99	1.98 ± 0.25	
R8-1	8.08 ± 1.15	6.67 ± 1.34	4.75 ± 0.35	
R26	11.03 ± 1.85	7.78 ± 1.23	8.43 ± 0.08	8.14 ± 0.50
Average	7.44^{c}	5.90^{a}	3.71^{a}	8.14
F_1 Crosses				
A14 × R-8-1	5.29 ± 0.99	7.20 ± 1.03	3.02 ± 0.24	
A24 × R-8-1	6.98 ± 0.15	3.58 ± 0.28	2.33 ± 0.11	
C9 × R5	5.30 ± 0.82	3.92 ± 1.28	3.66 ± 0.49	
A7 × R5	9.23 ± 0.78	1.97 ± 0.14	3.20 ± 1.51	
A9 × R-8-1	6.97 ± 0.52	3.66 ± 0.41	1.43 ± 0.11	
A9 × R26	5.47 ± 1.44	5.83 ± 0.40	3.79 ± 1.16	5.68 ± 1.91
A7 × R26	4.81 ± 1.93	3.93 ± 1.24	4.23 ± 1.12	4.39 ± 1.57
A24 × R26	10.42 ± 1.61	2.82 ± 0.26	4.27 ± 0.96	
A14 × R26	10.58 ± 2.51	4.26 ± 0.77	1.86 ± 0.46	9.38 ± 0.67
A6 × R26	7.64 ± 0.64	7.26 ± 1.07	5.81 ± 1.22	8.14 ± 0.59
Average	8.67^{b}	4.45^{b}	3.36^{b}	6.9
Commercial hybrid				
Hysun33	12.09^{a} ± 1.08	4.47^{b} ± 0.61	2.17^{b} ± 0.80	
S278	7.43^{c} ± 1.07	1.68^{c} ± 0.53	0.95^{c} ± 0.52	

[abc]Means within a column followed by different letters are significantly ($p \leq 0.05$).

Response of selected hybrids under weed infestation regimes

Analyses of variance for both traits (seed yield per plant and oil contents %) showed significant ($p \leq 0.05$) variation due to hybrids, years and weed infestation regimes. Hybrids × weed infestation regimes was insignificant but hybrids × years interaction was significant ($p \leq 0.05$) for seed yield (S2). Hybrids × year effects was insignificant ($p \geq 0.05$) for oil contents (Table S2). There was 23% decrease in seed yield per plant in field condition consecutively over two years while there was decrease of 10% and 16% for oil contents during the year 2015 and 2016,

Table 5: Mean values of head weight (g) as affected by the contrasting weed regimes and chemical control of weeds (*Cyperus rotundus*) in sunflower (*Helianthus annuus* L.).

Genotype	Weeds infestation regime			Chemical spray
	Control	5	10	
Parents				
B6	4.53 ± 1.27	1.63 ± 0.19	0.75 ± 0.20	
B7	2.71 ± 0.33	2.57 ± 0.85	1.73 ± 0.50	
B9	1.86 ± 0.13	1.43 ± 0.11	1.37 ± 0.16	
R5	3.73 ± 0.22	0.21 ± 0.03	0.13 ± 0.02	
R-8-1	3.76 ± 0.36	0.35 ± 0.09	0.84 ± 0.14	
R26	3.30 ± 0.92	2.12 ± 0.18	1.83 ± 0.03	1.59 ± 0.08
Average	3.32^c	1.42^a	1.14^a	1.59
F_1 Progenies				
A14 × R-8-1	2.98 ± 0.15	1.67 ± 0.44	1.77 ± 0.22	
A24 × R-8-1	5.47 ± 0.84	1.45 ± 0.39	1.29 ± 0.08	
A9 × R5	5.64 ± 0.67	3.83 ± 0.76	2.71 ± 0.72	
A7 × R5	2.21 ± 2.08	0.91 ± 2.08	0.73 ± 2.08	
A9 × R-8-1	3.45 ± 0.31	1.27 ± 0.06	0.86 ± 0.14	
A9 × R26	5.59 ± 2.83	2.84 ± 0.12	2.29 ± 0.14	1.25 ± 0.38
A7 × R26	4.08 ± 1.01	0.60 ± 0.42	0.17 ± 0.02	0.81 ± 0.24
A14 × R26	15.27 ± 0.85	2.27 ± 0.08	1.62 ± 0.10	4.68 ± 0.24
A6 × R26	13.63 ± 1.55	3.58 ± 0.48	2.31 ± 0.42	0.25 ± 0.33
Average	6.45^b	2.04^a	1.52^a	1.74
Hysun33	12.54^a ± 0.89	0.42^b ± 0.26	0.36^b ± 0.07	
S78	4.42^c ± 0.87	0.29^b ± 0.13	0.19^b ± 0.13	

^{abc}Means within a column followed by different letters are significantly ($p \leq 0.05$).

respectively. Hybrid C10, C7, C-1 followed by Hysun-33 showed the highest seed yield in control (Figure 2). Commercial hybrid S-278 followed by C2, and C9 showed the highest oil contents (%) under control conditions (Figure 2). Weed infestation regime showed repressing effects on oil contents % when compared with control in both years. C2 showed the highest oil contents under weed infestation regime followed by C9, while commercial hybrids (Hysun-33 and S278) showed the lowest oil contents under weed infestation regime averaged over two years (Figure 2).

Discussion

Weed infestation regimes posed significant effects over biochemical and morphological traits. Sensitivity of these traits to the weed infestation regimes

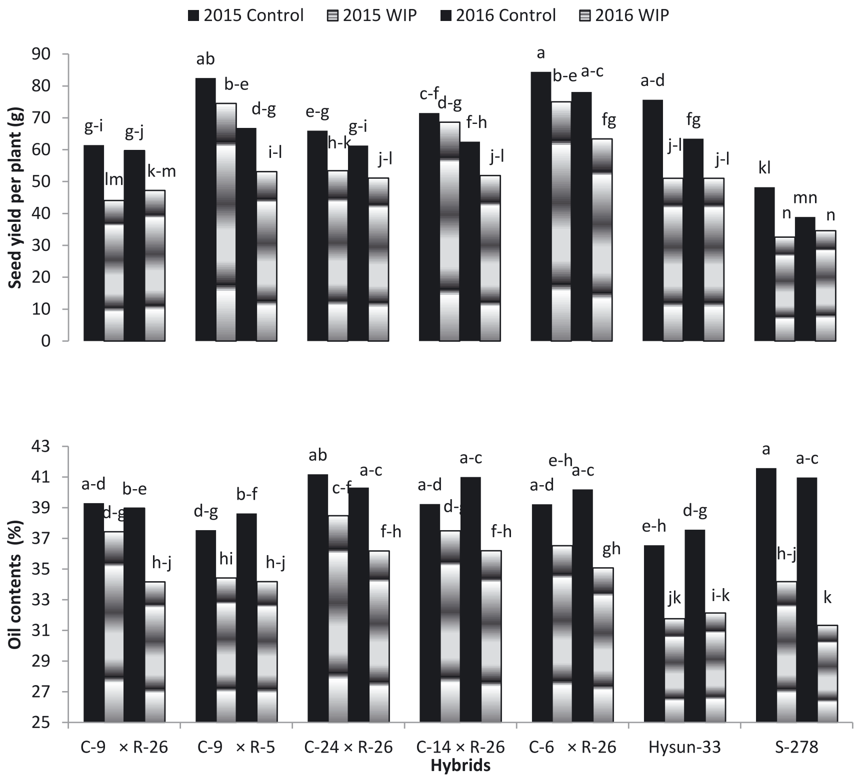

Figure 2: Seed yield and oil content plant^{-1} for various cross combinations in sunflower as affected by contrasting weed regimes.

indicated that these traits could be utilized for the discriminating genotypes due to their reduction in mean values under stress regimes. Leaf area showed the highest reduction due to weed infestation which may detrimental impact on photosynthates production and leaf gas exchange (Kalyar et al. 2013) which may ultimately impact biomass accumulation in plants as indicated by significant decline in head weight of hybrids and parental lines (Table 5). Moreover, it was also concluded that weed infestation caused significant ($p \leq 0.05$) yield and oil contents (%) losses in susceptible hybrids in field trial conducted over two years. Major cause of this damage was the release of allelochemicals by *Cyperus rotundus* which retarded growth and development of host crop species (Peerzada 2017). In addition, it also shared nutrients, moisture, light and space with crop. However, variation existed between and within species for good co-existence which may provide a long term solution of weed management without increasing the production cost of crop species (Mohammadi 2013). Results showed that resistant cross combinations such as C8, C3, C10, C7, C6 experienced significant lower yield losses when compared with control (Figure 2). Sunflower germination and seedling growth was adversely affected by the weed infestation (Lewis and Gulden 2014). It lowered sunflower yield up to 76% when weed growth was unchecked during early growth phase of sunflower (Lewis and Gulden 2014). However, there was no effect on plant height and number of leaves per plant. There was non-significant effect on yield and yield contributing traits when weeds (*Kochia scoparia*) were germinated at 4 leaf stage in sunflower (Lewis and Gulden 2014).

Sunflower breeding lines and hybrids showed significant ($p \leq 0.05$) variation for resistance against weeds. In sunflower, germplasm have been screened to characterize herbicide resistant genes (Jacob et al. 2017) but no studies were carried out to select sunflower genotypes which may show better co-existence with weeds to reduce the cost of sunflower production. One way to introgress resistance against weed was to enhance the crop competitive ability by enhancing crop tolerance, through the ability of crop plant to interference the weeds by the release of allelochemicals (Bajwa et al. 2017; Presotto et al. 2017). Traits such as leaf area index, biomass accumulation, plant height and plant canopy density were important traits to be evaluated for crop competitive ability (Mohammadi 2013).

Sunflower possesses several allelopathic chemicals such as chlorogenic acid, isochlorogenic acid, α-naphthol, scopolin and annuionones (Rawat et al. 2017). Alsaadawi et al. (2012) conducted chromatographic analysis of which showed that there were about 13 secondary metabolites in different sunflower genotypes. The most suppressing sunflower genotypes had higher concentration of these metabolites as compared to least suppressing genotypes. Development of weed resistant hybrids may help to reduce yield losses due to greater competitive ability. Weed resistant hybrids may also help to check down the over use of herbicides. Over use of herbicide have the ecological impacts such as accumulation of pollutants and evolution of herbicide resistant weeds (Al-Samarai et al. 2018).

This study finds some weed resistant hybrids (C10, C3, C8 and C6) and inbred lines (B-6, B-7 and R-26) which showed better performance than standard hybrids under weed infestation regimes. Parental lines may be shared among the breeder to develop resistant hybrids. A promising cross combination C10 (C-6 × R-26) had better antioxidant production, leaf area; higher biomass accumulation and seed yield under field condition could be further evaluated to develop weed resistant hybrids.

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