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Article

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Weed Management in Wheat by Cuscuta Alone and in Combination with Commercial Weedicides Allymax and Axial

Manejo de Plantas Daninhas em Trigo por Cuscuta Isoladamente e em Combinação com Herbicidas Comerciais Allymax e Axial

ABSTRACT - The present study was to assess the additive effects of cuscuta (akasbel) aqueous extract alone and in combination with full and reduced doses of commercially available weedicides against weeds in wheat crop during the year 2016-2017. The study was conducted in a randomized complete block design (RCBD) with 3 replications. The results showed that hand weeding and use of weedicides Allymax and Axial (full and half recommended doses) significantly controlled all prevailing weeds and increased yield and yield contributing parameters over the weedy check/control and sole application of cuscuta aqueous extract. Hand weeding and Allymax (full dose) showed minimum weed population, relative density, fresh and dry weed biomass and higher leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), plant height, 1000 grain weight and grain yield while net assimilation rate (NAR), chlorophyll content, number of tillers, spike length, grains spike^{-1} and biological yield were maximum only in hand weeding. These findings suggest that in order to attain highest wheat yield, the field should be kept free from weeds by hand weeding (if labour is not a limiting factor) or use recommended dose of weedicide Allymax for efficient weed management in wheat.

Keywords: wheat, weedicides, management, density.

RESUMO - O presente estudo objetivou avaliar os efeitos aditivos do extrato aquoso de Cuscuta (akasbel) isoladamente e em combinação com doses cheias e reduzidas de herbicidas comercialmente disponíveis contra plantas daninhas na cultura do trigo durante o ano de 2016-2017. O estudo foi conduzido em delineamento experimental de blocos casualizados (RCBD) com três repetições. Os resultados mostraram que a capina de mão e o uso de herbicidas Allymax e Axial (doses cheia e meia recomendadas) controlaram significativamente todas as plantas daninhas prevalecentes e aumentaram o rendimento e os parâmetros contribuintes de rendimento sobre a verificação de plantas daninhas e aplicação única de extrato aquoso de cuscuta. A capina de mão e Allymax (dose total) mostraram população mínima de plantas daninhas, densidade relativa, biomassa de plantas daninhas fresca e seca e maior índice de área foliar (LAI), duração da área foliar (LAD), taxa de crescimento da cultura (CGR), altura da planta, peso de mil grãos e rendimento de grãos, enquanto a taxa de assimilação líquida (NAR), teor de clorofila, número de perfilhos, comprimento de espiga, grãos de espiga^{-1} e rendimento biológico foram máximos apenas na capina de mão. Esses resultados sugerem que, a fim de atingir o maior rendimento de trigo, o campo deve ser mantido livre de plantas daninhas por capina de mão (se o trabalho não é um fator limitante) ou usar a dose recomendada do herbicida Allymax para o manejo eficiente de plantas daninhas em trigo.

Palavras-chave: trigo, herbicidas, gestão, densidade.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is a staple food crop of Pakistan. Area under wheat has decreased from 9199 to 9180 thousand hectares in Pakistan (Anonymous, 2015) and this reduction in yield, is mainly due to weed infestation. Weeds compete with crop plants for nutrients, moisture, carbon dioxide, light, temperature etc. and may cause yield reduction up to 70% in some wheat growing areas (Amare, 2014; Iqbal et al., 2018).

Weeds occur almost in every field and are a serious threat to crop production. They infest different crops and inflict negative effect on their yield and therefore their proper management through best available techniques is indispensable for obtaining higher crop yields. Weeds can be controlled by manual, mechanical, chemical and biological methods. Hand weeding is laborious and time consuming. Similarly, chemical weed control is a most efficient, labour and time saving method, its high cost cannot easily be afforded by the ordinary wheat grower (Iqbal et al., 2018).

Wheat being edible to human, usage of chemical weedicides is not desirable and manual weed control is the practice which is economically not viable. Hence, the use of biological and natural methods of weed control needs to be investigated in modern agricultural systems (Mubeen et al., 2012). This is on account of the utilization of synthetic weedicides, which is quickly expanding and disturbing the environment (Omezzine et al., 2011). In this manner, the allelopathic association of plants should be utilized as conceivably safe weedicides (Miri, 2011). Allelopathy is the concealment of one species by another because of poisonous chemicals; both negative and positive aspects are incorporated in this phenomenon (Kabir et al., 2010; Shah et al., 2016). Several researchers have reported weed species having inhibitory effects on weeds (Khalid et al., 2002; Javaid et al., 2005) while their negative effects on seed germination and seedlings growth of economically important crop plants have also been stated (Mulatu et al., 2009; Shah et al., 2017a).

Cuscuta spp. (dodder), also known as akasbel, are among those parasitic plants which have ability to suppress the growth, reproduction, other biochemical and physiological processes of the host plants. The most common species of cuscuta are *C. campestris* and *C. reflexa*. *Cuscuta reflexa* belongs to convolvulaceae family and is a holo-parasitic vine. It attacks the aerial parts of shrubs and trees (Khan et al., 2008). It is extensively spreading in various parts of the world, especially in temperate and subtropical ecosystems (Khan et al., 2008). Some cuscuta spp. has important medicinal and edible values, nonetheless, others have a threat to the natural ecosystems and agricultural crops (Jayasinghe et al., 2004). Depending upon the severity of infestation, cuscuta can reduce the crop yields by 27-100% (Mishra, 2009). Holm et al. (1979) listed *Cuscuta reflexa* as a serious weed in Afghanistan, Nepal, India and Pakistan.

It is, therefore, imperative to evaluate this parasitic plant against different weeds infesting field crops. Keeping that in view, an experiment was conducted in order to assess the allelopathic potential of cuscuta (akasbel) and to investigate the additive effects of dodder alone and in combination with commercially available weedicides against weeds in wheat crop.

MATERIALS AND METHODS

The experiment was laid out at the Agronomic Research Area, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa (KPK), Pakistan during the year 2016-2017. The experimental area was well prepared to make sure a fine seedbed. The sowing time of crop was November. The sowing method was followed by hand drill. A spacing of 30 cm between the rows and 10 cm between the plants were maintained for optimum plant population per unit area. The net plot size was 1.8 m × 5 m. Cultivar Faisalabad-8 was used with recommended seed rate of 100 kg ha^{-1}. The design was used randomized complete block design (RCBD) with 3 replications. Fertilizer doses (150:120:90 NPK kg ha^{-1}) were applied in the form of Urea, Di-Ammonium Phosphate and Potassium Sulphate, respectively in all treatments. Half dose of N and all the P_2O_5 and K_2O were applied at the time of sowing while remaining half N was top dressed with first irrigation. All other agronomic practices were followed uniformly as per standard recommendations of the

area. Weedicide (Allymax) was used to control broad leaf weeds while Axial was applied for controlling narrow leaf weeds. The specific experimental detail is given as under:

Treatments:

T_1 = Weedy check (control)

T_2 = Hand weeding

T_3 = Allymax (Full recommended dose)

T_4 = Allymax (Half recommended dose)

T_5 = Axial (Full recommended dose)

T_6 = Axial (Half recommended dose)

T_7 = Cuscuta aqueous extract (Full dose)

T_8 = Cuscuta aqueous extract (Full dose) + Allymax (Half dose)

T_9 = Cuscuta aqueous extract (Full dose) + Axial (Half dose)

T_{10} = Cuscuta aqueous extract (Half dose) + Allymax (Half dose)

T_{11} = Cuscuta aqueous extract (Half dose) + Axial (Half dose)

Cuscuta plant was collected from the nearby fields and shade dry for 96 hours. The water extract was prepared by soaking cuscuta plant in distill water a ratio of 1:5 for 72 hours, and then filter to collect the extracts. The extract was concentrated to 20 times by boiling at 1000 °C on a gas burner. Aqueous extracts of cuscuta and commercial weedicides were applied alone and in combinations at 30, 60 days after sowing (DAS). Physiological parameters were recorded as by following formula's which are given below:

Leaf area index (LAI) was measured by following formula (Shah et al., 2017b).

$$LAI = \frac{\text{Leaf area}}{\text{Land area}} \quad \text{(eq. 1)}$$

Leaf area duration (LAD) was measured by following formula (Nadim et al., 2011).

$$LAD = LAI \times M \quad \text{(eq. 2)}$$

where M is the number of weeks in the crop growth period.

Crop growth rate (CGR) was calculated by following formula (Shah et al., 2017b).

$$CGR = \frac{W2-W1}{T2-T1} \times \frac{1}{\text{Land area}} \ (g\ m^{-2}\ d^{-1}) \quad \text{(eq. 3)}$$

where, W_1 and W_2 are plant dry weights taken at time T_1 and T_2 respectively.

Net assimilation rate (mg m^{-2} day^{-1}) was calculated by using the following formula (Nadim et al., 2011).

$$NAR = \frac{(W2-WI)(Ln(LA2)-Ln(LA1))}{(T2-T1)(LA2-LA1)} \quad \text{(eq. 4)}$$

where W1 and W2 are dry weight, LA1 and LA2 are the leaf area, T2 and T1 are time interval, Ln is the natural log.

Chlorophyll was determined by following the method of Zhang et al. (2014).

Statistical analysis of data

The data were analyzed statistically by using analysis of variance techniques (Steel et al., 1997) and Duncan multiple range test was applied to see the level of significance, if any, among treatments with the help of "Statistics" software.

RESULTS AND DISCUSSION

Weed density (m^{-2}) and relative density (%)

The data presented in (Table 1) showed that weed density was non-significantly affected at 35 days after sowing (DAS) while a significant reduction in weed population was noted at 70 DAS. Among various treatments, maximum weed density (83.00 and 157.67 m^{-2}) was recorded in weedy check which was followed by cuscuta aqueous extract (full dose) + Axial (half dose) with weed population of 80.00 and 113.33 m^{-2} and cuscuta aqueous extract (half dose) + Axial (half dose) with weed density of 77.33 and 95.67 m^{-2} at 35 and 70 DAS, respectively.

Table 1 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on weed density (m^{-2}) of wheat at 35 and 70 DAS

Treatment	Weed density	
Weedy check (control)	83.00^{NS}	157.67 a
Hand weeding	64.66	32.33 e
Allymax (Full recommended dose)	65.33	35.67 e
Allymax (Half recommended dose)	74.33	56.67 de
Axial (Full recommended dose)	69.33	85.67 bcd
Axial (Half recommended dose)	77.00	86.33 bc
Cuscuta aqueous extract (Full dose)	67.33	93.33 b
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	70.66	48.33 e
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	80.00	113.33 b
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	69.00	59.33 cde
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	77.33	95.67 b
$LSD_{0.05}$	---	29.097

Different letters in a column are statistically significant at 5% probability level. NS = Non significant.

Minimum weed density (64.66 and 32.33 m^{-2}) was recorded in hand weeded plots at 35 and 70 DAS. It was, however, statistically at par with Allymax (full dose), cuscuta aqueous extract (full dose) + Allymax (half dose) with 65.33, 35.67 and 70.66, 48.33 weeds m^{-2}, respectively. In this study, the higher weed density in control plots was due to weeds remained unchecked throughout the growing season. Similarly, the cuscuta aqueous extract when applied alone or tank mixed with herbicides showed comparatively higher weed population than hand weeding. It implies that cuscuta had less suppressing effects against the targeted weed flora due to species or concentration compatibility. Mishra et al. (2004) found that aqueous leachates up to 5% concentration were non-toxic, further increase in concentration significantly inhibited the germination and seedling length of weeds.

On the other hand, the lower weed population in hand weeding might be related to suppression of weed growth, as they were uprooted to a large extent and later suppressed by the crop (Baloch et al., 2005). Razzaq et al. (2010) assessed weed management through combination of plant aqueous extracts with reduced doses of weedicides. They noted that total weed density was significantly influenced by different combinations of plant aqueous extracts with minimum (70%) doses of commercial weedicides. These results are also in line with Arif et al. (2015) who stated that overall weed density was lower in treatment combination as compared to weedy check.

Relative weed density results indicated maximum relative density of 23.6%, 32.2%, and 24%, 30% and 22%, 29.45% for broad leaf weeds (lambs quarter, bur clover, white melilot), respectively was recorded in weedy check at 35 and 70 DAS. Similarly, maximum relative density of narrow leaf weeds (14.6% and 21.3%) for canary grass, 7.5% and 11% for field bind weed) was also noted in control. Hand weeding, on the other hand, showed the minimum relative densities of 6.5%, 5.5%, 10.6%, 4.7% and 14%, 4.7% for the broad leaf weeds and 6.6%, 4.3% and 3.6%, 1.3% for narrow leaf weeds in this study. Axial (full dose) and Axial (half dose) also showed comparatively less relative density of narrow leaf weeds than rest of all treatments including Allymax (full and half dose). This is because Axial has better suppressing effects on narrow leaf than broad leaf weeds (Table 2).

Table 2 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on relative density (%) of wheat

Treatment	Broad Leaf Weed						Narrow Leaf Weed			
	Lambs quarter		Bur clover		White melilot		Canary grass		Field bind weed	
	35 days	70 days	35 days	70 days	35 days	70 days	35 days	70 days	35 days	70 days
Weedy check (control)	23.6	32.2	24.0	30	22.0	29.45	14.6	21.3	7.5	11.0
Hand weeding	6.2	5.5	10.6	4.7	14.0	4.7	6.6	4.3	3.6	1.3
Allymax (Full recommended dose)	8.4	6.7	11.6	5.3	14.5	5.1	12.3	11.6	6.0	8.4
Allymax (Half recommended dose)	11.7	7.7	13.9	7.6	16.3	7.1	11.0	15.0	7.0	9.2
Axial (Full recommended dose)	14.6	13.2	16.7	19.6	21.6	20.1	7.0	6.0	5.0	2.2
Axial (Half recommended dose)	19.6	15.4	17.0	22.7	21.3	23.4	7.0	7.4	5.0	4.0
Cuscuta aqueous extract (Full dose)	19.6	10.6	15.3	15.4	21.0	12.1	13.0	13.0	6.2	9.0
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	12.0	9.3	16.6	7.9	18.6	10.4	13.0	14.0	8.0	9.6
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	16.7	21.0	22.5	19.3	21.3	26.3	8.0	8.2	4.6	3.8
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	13.3	13.5	15.6	8.5	17.3	9.4	14.0	18.0	6.4	8.4
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	17.5	21.6	23.6	20.3	19.3	23.3	10.7	11.0	7.0	4.4

Fresh and dry weed biomass (g m^{-2})

As shown in (Table 3) fresh weed biomass was non-significantly affected by the studied treatments at 35 DAS however, significant effect was found at 70 DAS. Weedy check, cuscuta aqueous extract (full dose) + Axial (half dose), cuscuta aqueous extract (half dose) and Axial (half dose) produced maximum fresh weed biomass (21.42, 34.19 and 21.03, 28.36 and 19.86, 26.76 g m^{-2}) at 35 and 70 DAS, respectively. Next in order were Axial (half dose) and Axial (full dose) treatments with fresh weed biomass of 19.12, 25.80 and 18.90, 21.71 g m^{-2}, respectively. The lowest fresh weed biomass was recorded in hand weeding (13.30 and 8.84 g m^{-2}) followed by Allymax (full dose) with 13.90 and 10.78 g m^{-2}, respectively.

Table 3 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on fresh and dry weed biomass (gm^{2}) of wheat at 35 and 70DAS

Treatment	Fresh weed biomass		Dry weed biomass	
	35 DAS	70 DAS	35 DAS	70 DAS
Weedy check (control)	21.42 ^{NS}	34.19 a	4.41 ^{NS}	6.91 a
Hand weeding	13.30	8.84 e	2.89	1.78 f
Allymax (Full recommended dose)	13.90	10.78 de	3.04	2.21 e
Allymax (Half recommended dose)	16.57	15.10 cde	3.20	2.43 ef
Axial (Full recommended dose)	18.90	21.71 bc	3.99	4.73 bc
Axial (Half recommended dose)	19.12	25.80 ab	3.81	4.32 bcd
Cuscuta aqueous extract (Full dose)	16.01	20.79 bcd	3.53	4.03 be
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	13.70	14.68 cde	3.21	2.98 def
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	21.03	28.36 ab	3.74	4.29 bcd
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	16.75	12.60 cde	3.44	2.46 ef
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	19.86	26.76 ab	4.11	4.90 b
$LSD_{0.05}$	---	9.50	---	1.628

Different letters in a column are statistically significant at 5% probability level. NS = Non significant.

Highest fresh weed biomass, especially in weedy check, was due to the reason that no weed management practices were followed in these treatments and growth of weeds remained unchecked throughout the growing season. Conversely, hand weeding and Allymax (full dose)

treatments restricted weeds growth to that extant where they could not compete with crop plants for available resources. Sharif et al. (2005) reported that Mesosulfuron Methyl at the rate of 10.8 g ha^{-1} was the most effective treatment in reducing total weed density and dry weight up to 84.75 and 86.48%, respectively. Hussain et al. (2014) reported that combination of allelopathic extracts with lower rates of herbicide decreased weed density, fresh and dry weights by 42-70, 38-62 and 37-63%, respectively.

Dry weed biomass was non-significantly influenced by cuscuta aqueous extracts alone and in combination with weedicides at 35 DAS while a significant reduction in dry weight was noted at 70 DAS. Maximum dry weed biomass (4.41 and 6.91 g m^{-2}) was recorded in control. This was followed by 4.11 and 4.90 g m^{-2} recorded for cuscuta aqueous extract (half dose) + Axial (half dose) at 35 and 70 DAS, respectively (Table 3).

Next in order were Axial (full dose) with 3.99 and 4.73 g m^{-2}, Axial (half dose) with 3.81 and 4.32 g m^{-2}, cuscuta aqueous extract (full dose) + Axial (half dose) with 3.74 and 4.29 g m^{-2} and cuscuta aqueous extract (full dose) showing dry weed biomass of 3.53 and 4.03 g m^{-2}, respectively. Previous research findings also confirmed that the application of Axial 050 EK at the rate of 600 cm^3 ha^{-1} had the weakest impact (16.7%) on the grounds that it controls just the monocotyledonous weeds (Dimitrova et al., 2015).

In the present study, minimum dry weed biomass was noted in hand weeding (2.89 and 1.78 g m^{-2}) and Allymax (full dose) treatments with 3.04 and 2.21 g m^{-2}, respectively. It was due to lower weed populations and their fresh weight on account of proper weed management at initial and critical growth stages of crop which decreased competition between wheat plants and weeds. Jabran et al. (2010) studied crop water extracts including sorghum, sunflower, mustard and rice each at 15 L ha^{-1} were tank mixed with 0.4 and 0.6 kg ha^{-1} pendimethalin and sprayed immediately after sowing. They found that weed density, fresh weight and dry weight were lower than control in all the treatments.

Leaf area index and leaf area duration (m^{-2})

The data given in (Table 4) showed that leaf area index (LAI) was significantly affected by the studied treatments at 35 and 70 DAS. Statistical analysis revealed that maximum leaf area index (0.072 and 2.34) was recorded in hand weeding, which was followed by statistically at par values of 0.070 and 2.34 in Allymax (full dose) treatment. Next in order was Allymax (half dose) with LAI of 0.070 and 2.27. Cuscuta aqueous extract (full dose) + Allymax (half dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) showed LAI of 0.070, 2.25 and 0.070, 2.24, respectively. Minimum LAI (0.066 and 2.11) during the same period was recorded in control.

Table 4 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on leaf area index and leaf area duration (m^{-2}) of wheat at 35 and 70DAS

Treatment	Leaf area index		Leaf area duration	
	35 DAS	70 DAS	35 DAS	70 DAS
Weedy check (control)	0.066 b	2.11 f	0.331 b	21.100 f
Hand weeding	0.072 a	2.34 a	0.361 a	23.400 a
Allymax (Full recommended dose)	0.070 ab	2.34 a	0.355 ab	23.400 a
Allymax (Half recommended dose)	0.070 ab	2.27 b	0.353 ab	22.700 b
Axial (Full recommended dose)	0.069 ab	2.18 cde	0.345 ab	21.833 cde
Axial (Half recommended dose)	0.069 ab	2.15 def	0.341 ab	21.233 def
Cuscuta aqueous extract (Full dose)	0.068 ab	2.19 cd	0.341 ab	21.900 cd
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	0.070 ab	2.25 bc	0.353 ab	22.500 bc
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	0.068 ab	2.11 ef	0.336 ab	21.167 ef
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	0.070 ab	2.24 bc	0.348 ab	22.400 bc
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	0.067 ab	2.12 def	0.338 ab	21.567 def
$LSD_{0.05}$	0.001	0.068	0.025	0.687

Different letters in a column are statistically significant at 5% probability level.

The obtained data indicated that combination of aqueous extracts of cuscuta and reduced dose of weedicides was as effective as application of weedicides alone or hand weeding in terms of leaf area index. It might be attributed to lower weed density which exerted a reduced amount of stress on crop plants at 35 and 70 DAS while minimum LAI in weedy check was due to poor plant growth owing to higher weed population. These results are supported by Noor et al. (2012) who recorded minimum leaf area index in weedy check due to maximum number of weeds.

Nonetheless, leaf area duration (LAD) was significantly affected by cuscuta aqueous extracts alone and in combination with weedicides at 35 and 70 DAS. The data followed the same trend as recorded for leaf area index. Hand weeding had maximum LAD (0.361 and 23.400 m^{-2}) which was statistically similar to Allymax (full dose) with respective values of 0.355 and 23.400 m^{-2} at 35 and 70 DAS, respectively. Next in order were cuscuta aqueous extract (full dose) + Allymax (half dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) with statistically similar LAD of 0.353, 22.500 and 0.348, 22.400 m^{-2}. Lowest LAD (0.331 and 21.100 m^{-2}) was noted in control (Table 4). All the treatments performed significantly better than the control envisaging the futuristic approach of integrated weed management through aqueous extracts of cuscuta with reduced doses of weedicides. This implies that these aqueous plant extracts have greater potential to inhibit weeds growth by affecting cell division and elongation. The active compounds of cuscuta may interfere with production or transportation of plant hormones viz. cytokinins and auxins that cause cell division and cell elongation. In the present study, the maximum LAD recorded in hand weeding at 35 and 70 DAS and Allymax (full dose) was due to flourishing vegetative growth of crop plants by using all available resources efficiently. Minimum LAD in weedy check was attributed to presence of higher number of weeds in this treatment.

Crop growth rate (g m^{-2} day^{-1}) and Net assimilation rate (g m^{-2} day^{-1})

Crop growth rate (CGR) was considerably affected by the studied treatments. The analysis of mean values revealed that maximum CGR (0.136, 0.136 and 0.123 g m^{-2} day^{-1}) was noted in hand weeding, Allymax (full dose) and Allymax (half dose), respectively. These were, however, found statistically at par with each other and were followed by cuscuta aqueous extract (full dose) + Allymax (half dose) treatment giving CGR of 0.120 g m^{-2} day^{-1}. Cuscuta aqueous extract (half dose) + Allymax (half dose) with CGR of 0.133 g m^{-2} day^{-1} was next to follow. Axial (full dose), Axial (half dose), cuscuta aqueous extract (full dose), cuscuta aqueous extract (full dose) + Axial (half dose) stood next in queue with statistically similar values of 0.103, 0.103, 0.100 and 0.100 g m^{-2} day^{-1}. Minimum and statistically similar values were shown by cuscuta aqueous extract (half dose) + Axial (half dose) and weedy check (0.093 and 0.093 g m^{-2} day^{-1}), respectively (Table 5). In the present study, maximum CGR was noted in hand weeding and Allymax (full dose) treatments due to less competition between crop plants and weeds than the weedy check where

Table 5 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on crop growth rate (g m^{-2} day^{-1}) and net assimilation rate (gm^2 day^{-1}) of wheat

Treatment	Crop growth rate	Net assimilation rate
Weedy check (control)	0.093 d	0.032 f
Hand weeding	0.136 a	0.054 a
Allymax (Full recommended dose)	0.136 a	0.053 ab
Allymax (Half recommended dose)	0.123 ab	0.048 b
Axial (Full recommended dose)	0.103 cd	0.039 cde
Axial (Half recommended dose)	0.103 cd	0.034 ef
Cuscuta aqueous extract (Full dose)	0.100 cd	0.036 def
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	0.120 b	0.041 d
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	0.100 cd	0.035 def
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	0.113 bc	0.039 cde
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	0.093 d	0.035 def
$LSD_{0.05}$	0.014	4.66

Different letters in a column are statistically significant at 5% probability level.

growth of weeds remained unchecked throughout the growing season. Nonetheless, net assimilation rate (NAR) was significantly affected by the studied treatments. Hand weeding showed the maximum NAR (0.054 g m^{-2} day^{-1}) which was statistically similar to Allymax (full dose) with NAR of 0.053 g m^{-2} day^{-1}. These were followed by Allymax (half dose) and cuscuta aqueous extract (full dose) + Allymax (half dose) giving respective values of 0.048 and 0.0417 g m^{-2} day^{-1} for the aforementioned parameter. Next in order were statistically and numerically similar values of 0.039 g m^{-2} day^{-1} noted in Axial (full dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) treatments. Cuscuta aqueous extract (full dose), cuscuta aqueous extract (full dose) + Axial (half dose) and cuscuta aqueous extract (half dose) + Axial (half dose) followed the order with statistically similar NAR of 0.036, 0.035 and 0.035 g m^{-2} day^{-1}, respectively. Axial (half dose) presented the next higher value of 0.034 g m^{-2} day^{-1}. Minimum NAR (0.032 g m^{-2} day^{-1}) was recorded in weedy check (Table 5). The maximum net assimilation rate in hand weeding and Allymax (full dose) was attributed to translocation of higher number of salutes towards crop plants during vegetative growth stages owing to lower weed density in these treatments.

Chlorophyll content (µ g cm^{-2})

Chlorophyll contents were significantly affected by cuscuta aqueous extract alone and in combination with weedicides at 35 and 70 DAS. As far as the effect of different treatments is concerned, maximum chlorophyll contents (43.40 and 48.93 µg cm^{-2}) was obtained in hand weeding, which was statistically similar to that obtained in Allymax (full dose) treatment (43.13 and 48.80 µg cm^{-2}) at 35 and 70 DAS, respectively. These treatments were followed by Allymax (half dose) with chlorophyll content of 42.63 and 48.40 µg cm^{-2} and cuscuta aqueous extract (full dose) + Allymax (half dose) showing chlorophyll content of 41.83 and 48.30 µg cm^{-2}, respectively. Weedy check showed significantly minimum chlorophyll content of 41.03 and 46.56 µ g cm^{-2} (Table 6). These results indicated that maximum chlorophyll content recorded in hand weeding and Allymax (full dose) at 35 and 70 DAS were possibly due to lower number of weeds in these treatments. The reverse was true in case of weedy check where a large number of weeds remained in the experimental field and a keen competition for resources was going on between the crop plants and weeds throughout critical growth stages, supported by Reddy (2004).

Table 6 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on chlorophyll content (µ g cm^{-2}) of wheat

Treatment	Chlorophyll content	
	35 DAS	70 DAS
Weedy check (control)	40.60 d	46.56 e
Hand weeding	43.40 a	48.93 a
Allymax (Full recommended dose)	43.13 ab	48.80 ab
Allymax (Half recommended dose)	42.63 abc	48.40 abc
Axial (Full recommended dose)	41.10 cd	47.03 cde
Axial (Half recommended dose)	41.30 cd	48.20 abcd
Cuscuta aqueous extract (Full dose)	41.60 bcd	47.36 cde
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	41.83 bcd	48.30 abcd
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	41.10 cd	47.40 cde
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	41.46 cd	47.46 bcde
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	41.03 d	47.00 de
$LSD_{0.05}$	1.552	1.390

Different letters in same column are statistically significant at 5% probability level.

Yield and yield attributes

Number of tillers is one of the major yield contributing parameters. The data mentioned in (Table 7) indicated that hand weeding and Allymax (full dose) produced significantly maximum but statistically similar number of tillers of 344.33 and 339.33, respectively. Similarly, cuscuta

Table 7 - Effect of aqueous extract of cuscuta alone and in combination with commercial weedicides Allymax and Axial on number of tillers (1 m row), spike length (cm), number of grains (spike^{-1}), 1000 grain weight (g), grain yield (kg ha^{-1}) of wheat

Treatment	Number of tillers	Spike length	Number of grains	1000 grain weight	Grain yield
Weedy check (control)	319.33 e	7.96 e	31.53 e	43.26 e	2952.7 e
Hand weeding	344.33 a	9.18 a	37.56 a	49.43 a	4088.3 a
Allymax (Full recommended dose)	339.33 ab	8.86 ab	36.16 b	48.63 a	4027.7 a
Allymax (Half recommended dose)	328.00 cd	8.44 bcd	35.53 bc	45.96 bc	3567.0 c
Axial (Full recommended dose)	325.00 cde	8.03 de	32.63 d	45.23 bcd	3188.3 d
Axial (Half recommended dose)	320.67 de	8.14 cde	32.10 de	44.13 de	3255.3 d
Cuscuta aqueous extract (Full dose)	322.00 de	8.10 de	32.23 de	44.20 de	3195.0 d
Cuscuta aqueous extract (Full dose) + Allymax (Half dose)	331.67 bc	8.44 bcd	34.63 c	46.26 b	3721.3 b
Cuscuta aqueous extract (Full dose) + Axial (Half dose)	323.33 cde	8.12 de	32.16 de	44.66 cde	3022.0 e
Cuscuta aqueous extract (Half dose) + Allymax (Half dose)	331.67 bc	8.61 bc	34.73 c	45.23 bcd	3671.7 b
Cuscuta aqueous extract (Half dose) + Axial (Half dose)	321.33 de	8.04 de	31.60 de	43.90 de	2960.0 e
$LSD_{0.05}$	8.534	0.479	1.094	1.587	98.431

Different letters in same column are statistically significant at 5% probability level.

aqueous extract (full dose) + Allymax (half dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) produced statistically at par number of tillers (331.67 each). Next in order for number of tillers (328.00, 325.00, 323.33, 322.00, 321.33 and 320.67) were Allymax (half dose), Axial (full dose), cuscuta aqueous extract (full dose) + Axial (half dose), cuscuta aqueous extract (full dose), cuscuta aqueous extract (half dose) + Axial (half dose) and Axial (half dose), respectively. Tillers initiation is usually started 35 to 45 days after sowing wheat crop. At this time broad leaf weeds are mainly developed and compete with crop plants. In general, more tillers are produced when broad leaf weeds are managed properly at critical expansion period of tillers. In this study, the use of hand weeding and Allymax (full dose) treatments produced maximum number of tillers due to effective control of broad leaf weeds at the time of tillers initiation. The use of cuscuta aqueous extract (half dose) + Axial (half dose) produced minimum number of tillers in control due to less use of available resources on account of heavy weed infestation. Axial weedicide had better suppressing effects on narrow leaf weeds but in these treatments the population of broad leaf weeds remained higher which negatively affected tillers production during the initial growth stages of wheat. Hussain et al. (2014) investigated the effects of allelopathic extracts and their combinations with herbicide on weeds and yield of wheat.

Nonetheless, spike length was significantly affected by cuscuta aqueous extracts alone and in combination with weedicides. Among various treatments, maximum spike length (9.18 cm) was noted in hand weeding which was statistically similar to Allymax (full dose) with spike length of 8.86 cm. These were followed by cuscuta aqueous extract (half dose) + Allymax (half dose) with 8.61 cm spike length. Allymax (half dose), cuscuta aqueous extract (full dose) + Allymax (half dose) were next in order with similar spike length of 8.44 cm each. These were followed by Axial (half dose) with spike length of 8.14 cm. Cuscuta aqueous extract (full dose) + Axial (half dose), cuscuta aqueous extract (full dose), cuscuta aqueous extract (half dose) + Axial (half dose) and Axial (full dose) had spike length of 8.12, 8.10, 8.04 and 8.03 cm, respectively. Minimum spike length (7.96 cm) was recorded in control (Table 7). In this study, maximum spike length in hand weeding and Allymax (full dose) treatments was due to lower weed influx and sufficient availability of moisture, nutrients etc. to crop plants. Minimum spike length in control was due to higher competition for resources between weeds and crop plants. These results are in line with Chattha et al. (2014) who reported that the use of weedicides significantly affected all growth and yield contributing parameters including spike length over control. Rab et al. (2016) noted that weedicide treated plots had less weeds (39.0 m^{-2}) and lengthy spikes (10.57 cm) as compared to sorghum water extract sprayed plots.

The data given in (Table 7) showed that all the studied treatments significantly affected number of grains per spike. The maximum grains per spike (37.56) were noted in hand weeding, which was followed by Allymax (full dose) and Allymax (half dose) with 36.16 and 35.53 grains

per spike, respectively. Next in order were cuscuta aqueous extract (half dose) + Allymax (half dose) and cuscuta aqueous extract (full dose) + Allymax (half dose) presenting statistically similar grains per spike of 34.73 and 34.63, respectively. These were followed by Axial (full dose) producing 32.63 grains per spike while cuscuta aqueous extract (full dose), cuscuta aqueous extract (full dose) + Axial (half dose), Axial (half dose) and cuscuta aqueous extract (half dose) + Axial (half dose) had statistically at par number of grains per spike (32.23, 32.16, 32.10 and 31.60), respectively. Weedy check produced least number of grains per spike (31.53). The highest number of grains per spike recorded in hand weeding treatment was attributed to sufficient availability of nutrients to crop plants due to lower weed infestation and translocation of maximum salutes during grain formation. These results are supported by Khan et al. (2001, 2003) who reported that herbicidal application had maximum number of grains per spike over control where the growth of weeds remained unchecked throughout their growth period. Similarly, Hussain et al. (2014) revealed that combination of allelopathic extracts with lower rates of herbicide produced significantly maximum number of grains per spike in hand weeding than any other studied treatments.

Therefore, Grain weight was significantly affected by cuscuta aqueous extracts alone and in combination with weedicides. Among the studied treatments, heaviest grains (49.43 and 48.63 g) were produced in hand weeding and Allymax (full dose), respectively. Cuscuta aqueous extract (full dose) + Allymax (half dose) produced the second highest grain weight of 46.26 g. Following this was Allymax (half dose) giving 45.96 g grain weight. Next in line was numerically and statistically similar grain weight of 45.23 g each in Axial (full dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) treatments, respectively. Next in order was cuscuta aqueous extract (full dose) + Axial (half dose) with 44.66 g grain weight, whereas, cuscuta aqueous extract (full dose), Axial (half dose) and cuscuta aqueous extract (half dose) + Axial (half dose) had statistically similar grain weight of 44.20, 44.13 and 43.90 g, respectively. Minimum grain weight (43.26 g) was recorded in control (Table 7). The heaviest grain weight in hand weeding and Allymax (full dose) treatments was due to sufficient intake of nutrients, proper utilization of available space, light interception etc on account of lower weed invasion. The reverse was true in case of control where higher number of weeds was competing with crop plants for available resources. Jabran et al. (2010) studied lower doses of pendimethalin mixed with allelopathic crop water extracts for weed management in canola. Crop water extracts including sorghum, sunflower, mustard and rice each at 15 L ha^{-1} were tank mixed with 0.4 and 0.6 kg active ingredient ha^{-1} pendimethalin and sprayed immediately after sowing. They reported that all the yield contributing parameters, including 1000 seed weight, were higher where combinations of allelopathic extracts were used with lower herbicide rates. Similarly, Chattha et al. (2014) reported that the use of weedicides expanded all growth and yield contributing parameters including 1000 grain weight over the weedy check.

Therefore, grain yield was significantly affected by the studied treatments. Maximum grain yield of 4088.3 and 4027.7 kg ha^{-1} was recorded in hand weeding and Allymax (full dose) treatments, respectively. Cuscuta aqueous extract (full dose) + Allymax (half dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) stood second in queue producing statistically similar grain yield of 3721.3 and 3671.7 kg ha^{-1}, respectively. Allymax (half dose) was next in order with grain yield of 3567.0 kg ha^{-1}. Statistically at par grain yield of 3255.3, 3195.0 and 3188.3 kg ha^{-1} was recorded in Axial (half dose), cuscuta aqueous extract (full dose) and Axial (full dose), respectively. Lowest grain yield (2952.7, 2960.0 and 3022.0 kg ha^{-1}) was noted in control, cuscuta aqueous extract (half dose) + Axial (half dose) and cuscuta aqueous extract (full dose) + Axial (half dose), respectively (Table 7). These results are in line with Hashim et al. (2002) who reported that weedicide treatments produced significantly highest grain yield in wheat. These results are also supported by Iqbal et al. (2010), Khan et al. (2013) and Arif et al. (2015) who obtained highest grain yield in weedicide treated plots as compared to crop treated with aqueous extracts alone. Minimum grain yield in weedy check, cuscuta aqueous extract (half dose) + Axial (half dose) and cuscuta aqueous extract (full dose) + Axial (half dose) was due to higher weed density and competition between weeds and crop plants during critical growth stages. These results are supported by Arif et al. (2015) who stated that grain yield of wheat was increased substantially in all weed control treatments except weedy check. Khaliq et al. (2012) used water extracts of sorghum + sunflower + mulberry alone or combined with iodo+mesosulfuron against weeds in wheat and reported that the mixture of plant water extracts combined with reduced doses of iodo+mesosulfuron gave

weed control equal to the recommended dose of the herbicide and a wheat yield comparable to using the recommended herbicide dose.

Based on current research findings, it is concluded that hand weeding be practiced to keep wheat field free from weeds, if low-cost labor is available during critical crop growth periods. Otherwise, weedicide Allymax may be used as an alternative weed management technique in order to eradicate weeds and increase wheat yield per unit area. Sole application of cuscuta aqueous extract reduced weed population moderately. While, the combination of cuscuta aqueous extract (full dose) + Allymax (half dose) and cuscuta aqueous extract (half dose) + Allymax (half dose) showed much better results for suppressing weeds and increasing yield contributing parameters over weedy check and cuscuta aqueous extract (full dose) + Axial (half dose) and cuscuta aqueous extract (half dose) + Axial (half dose) treatments. Therefore, hand weeding and/or Allymax (full dose) is recommended for obtaining higher yield of wheat.

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