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Allelopathic Efficacy of Sorghum Mulches and Water Extract Concentrations on Weed Suppression and Yield Enhancement in Wheat

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Abstract: The weeds cause wheat production losses upto 50%, and in some cases they can result in total crop failure. Therefore, to overcome the historically burning issue of farming community this highly important study was carried out to determine how weed suppression through application of allelopathic mulches and water extracts of sorghum could increase wheat yield. The experiment was conducted under field conditions at Agronomy Section, Agriculture Research Institute, Tandojam, Pakistan during Rabi (winter) 2007-08 and same study was also repeated in next Rabi season of 2008-09 for accuracy of results. The experiment was laidout in three replicated randomized complete block design, having net plot size of 4 m x 3 m (12 m^2). The treatment consisted: weedy check (no weeding); sorghum mulches at 6 Mg ha^{-1} and 12 Mg ha^{-1} (soil incorporated and surface cover); sorghum water extract concentrations at 10 and 15 L ha^{-1} (1 and 2 sprays) at 4 and 6 weeks after sowing; and hand weddings (two) at 4 and 6 weeks after sowing. The results showed that sorghum organic mulches at 12 Mg ha^{-1} and water extract concentrations @ 15 L ha^{-1} (2 sprays) exhibited significant ($P< 0.05$) allelopathic effects on weeds. Herbage mulches at 12 Mg ha^{-1} and water extract concentrations (2 sprays) @ 15 L ha^{-1} respectively significantly ($P<0.05$) enhanced growth, yield and reduced the density m^{-2} and biomass of weeds in wheat. Agronomic and physiological traits of wheat such as plant height (96.50 cm) spike length (12.94 cm), grains spike^{-1} (67.76), grain weight spike^{-1} (3.75 g), spikes m^{-2} (356 and 339), biological yield (14. 70 and 14.41 Mg ha^{-1}) and grain yield (7.64 and 7.49 Mg ha^{-1}) and leaf area plant^{-1} (cm^2), leaf area index (%), dry matter production (m^{-2} (g/ kg) and crop growth rate (g m^{-2} day^{-1}) were recorded maximum with application of water extract concentrations @ 15 L ha^{-1} (2 sprays) at 4 and 6 after sowing and at sorghum mulch (soil incorporated) at 12 Mg ha^{-1} respectively as compared to weedy check. Although minimum weed density m^{-2} (8.33 and 5.13), fresh weed biomass (126.3 and 79.33 g) at 90 days after sowing, dry weed biomass (25.17 and 22.67g) and maximum weed control %age (77.86 and 86.3), were recorded with sorghum mulch (S.I) at 12 Mg ha^{-1} and sorghum water extract concentrations @ 15 L ha^{-1} (2 sprays) at 4 and 6 weeks after sowing respectively. Moreover, all organic mulches and water extract concentrations were found effective and economical as compared to weedy check.

Keyword::Allelopathy, Sorghum, Mulches, Extracts, Weeds, Wheat

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the major wide-spread grown crop and staple food of masses in the world. In Pakistan, wheat constitutes 60% of the average daily diet of a common man which is principally consumed as flat bread. Wheat yield adversely affected due weed infestation, about Weed reduces wheat yield by 17-50% (Abbass *et al*. 2010). About 24 weed species have been found to reduce the yield in wheat crop at high levels (Memon and Bhatti, 2003). Besides production losses in wheat weeds also negatively affect crop quality and its demand in market. Weeds capture the light, nutrients, soil water, CO_2 and occupy place more than cultivated crops and some weeds also exerts allelopathic ill-effects to the crops. Wheat production losses due to weeds in monetary terms are high as Rs.28 billion per year (Khan and Marwat, 2006). The farmers control weeds in wheat during land preparation. Khan *et al*., 2000; Carballido *et al*., 2013; Gianessi, 2013 investigated that the manual removal of weeds is tiring, time consuming, laborious and expensive. The cost of hand weeding is about Rs.5600 ha^{-1} and control of weeds through crop rotation has become rare at farmers field level (Narwal, 2000). A plentiful amount of Rs. 2.2 billion is being invested on the import of herbicides for wheat which accounts 63% of the total herbicide import (Ashiq *et al*., 2006). Non-judicious application of herbicides is impurifying environment, damaging crops, causing health hazards to human beings and animals, polluting soil and water (Jabran *et al*., 2008; Powles, 2008; Farooq *et al*., 2011; Annett *et al*., 2014; Hoppin, 2014; Starling *et al*., 2014; Jabran *et al*., 2015). Development of herbicidal resistance in weeds and many other environmental and health concerns compelled to search for alternative weed control strategies (Farooq *et al*., 2011; Jabran and Farooq, 2013; Zeng, 2014). The possible strategies for minimizing the use of herbicides to control weeds could be use of natural and allelopathic products for crop improvement and environmental safeguard (Hussain *et al*., 2007; Farooq *et al*., 2008; Pickett *et al*., 2014). The phenomenon of allelopathy can be practically

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utilized for weed suppression in the form of crop rotations, intercropping, allelopathic mulches and spray of allelopathic plant water extracts (Jabran *et al*., 2010a; Farooq *et al*., 2011). Allelopathy is a latest technology which is environmental friendly and most suitable for sustainable agriculture (Yongqing, 2005). Allelopathy is referred as either negative or positive impacts on crop plants by releasing chemicals, root exudations, disintegration of plant-parts and further natural as well as agricultural processes (Gibson and Liebman, 2003). Various researchers tested the allelopathic potential of different crops such as sorghum (Cheema *et al*., 2009; Jamil, *et al.,* 2009; Mushtaq *et al.,* 2010; Weston *et al*., 2013), sunflower (Cheema *et al*., 2005; Alsaadawi *et al*., 2012), brassica (Turk *et al.,* 2003), rice (Duke *et al.,* 2002). Allelopathic water extracts from sorghum, sunflower and *Brassica* were common as an alternative of herbicides for weed control which inhibited the population and dry mass of weeds such as broad leaf dock (*Rumax dentatus* L.), canary grass (*Phalaris minor* Retz), wild oat (*Avena fatua* L.), field bind weed (*Convolvulus arvensis* L.) and lambsquarters (*Chenopodium album* L.) up to 40-50% (Cheema *et al*., 2009). Sorghum is one of the most promising allelopathic crop (Alsaadawi, 2007) which contains number of allelochemicals from which fourteen have been reported by Mahmood (2003). The effects of these allelochemicals mostly depend upon species; concentration, their mobility, destiny and perseverance in soil (Inderjit, 2001; Weston *et al*., 2013). Allelopathic crops may be practiced in different ways to suppress weeds such as surface mulch (Cheema *et al*., 2000), incorporation into the soil (Sati *et al*., 2004), aqueous extracts (Javaid and Anjum, 2006; Iqbal and Cheema, 2007a), rotation (Narwal, 2000), smothering (Singh *et al*., 2003) or mix cropping / intercropping (Iqbal and Cheema, 2007b). In Sorgaab (sorghum cv. JS-263 water extract) seven allelochemicals were identified, these are benzoic acid, gallic acid, p-hydroxybenzoic acid, pcoumaric acid, protocateuic acid, syringic acid and vanillic acid. Parveen (2000) found caffeic, ferulic, chlorogenic, syringic and vanillic acid from sorghum plant (leaf and stem) water extracts through thin layer chromategraphic technique. Dhurrin (acyanogenic glycoside) (Nielsen *et al*., 2008; Weston *et al*., 2013) are also reported other important allelochemicals in sorghum plant. In many latest studies allelopathic ability of sorghum water extract has been established (Iqbal and Cheema, 2008). It has been reported that not only sorghum but also some other crop plants likewise sunflower (*Helianthus annuus* L.) possess allelopathy (Iqbal and Cheema, 2007, 2009). Moreover, allelopathic effects are concentration dependent as stated by Farooq *et al*., 2011; 2013. It is hypothesized that sorgaab and other plant extracts when used in combination, may be more effective against weeds (Cheema *et al.,* 2003c; Farooq *et al*., 2011; Elahi *et al*., 2011; Awan *et al*., 2012; Farooq *et al*., 2013. Allelochemical either plants release themselves actively (Ridenour and Callaway, 2001; Seal *et al.,* 2004) or generated after the decomposition of plant residues passively (Bonanomi *et al.*, 2006). Sorghum crop may be used in different ways to influence weeds such as surface mulch (Cheema *et al.,* 2000), incorporation into the soil (Ahmad *et al.*, 1995), spray of aqueous extracts (Cheema *et al.*, 2002), rotation (Narwal, 2000). Similarly aerial application of sorghum liquid extract reduced density and dry weight of purple nutsedge by 44% and 67%, respectively with an increase in maize grain yield up to 44% (Cheema *et al.,* 2001). Both sunflower and sorghum are popular allelopathic crops, which possess a numerous poisonous allelochemicals to weeds (Jabran *et al*., 2010a, b). Alleolochemicals have become efficient as well as recognized organic herbicides to control the weeds (Narwal, 2000; Chittapur *et al*., 2001; Nagabhushana *et al*., 2001; Reigosa *et al*., 2001; Xuan *et al*., 2002). The allelochemicals and herbicides are balancing for each other to enhance their efficiency, so, these can be used at lesser amount while mixed with each other (Cheema *et al.,* 2002). In a relevant study 35-49% weeds along with 10-20% wheat yield were resulted from sorghum. Weeds were controlled from 40-50% with the increase of 15% wheat yield resulted from mature sorghum mulch at the rate of 2-6 Mg ha^{-1} (Cheema and Khaliq, 2000; Mushtaq *et al.*, 2010). The core objectives of present study were to innovate the probability of utilizing sorghum material and their extract as an organic weed suppression technology for successful wheat cultivation in subtropical arid regions. The existing cropping scheme of the unit area is dependent on growing rotational cropping with wheat, cotton sugarcane and rice as main crops. The targeted objectives of our study were the comparison of modern techniques (Allelopathy) with traditional methods (hand weeding) for their biological and economic efficacy. Keeping in view the heavy infestation of weed species and causes huge losses in wheat production and allelopathic weed suppressing capacity of organic mulches and aqueous extract of sorghum on weed suppression in wheat and its effect on wheat yield.

2. MATERIALS AND METHODS

The field experiments were conducted at experimental field of Agronomy Section, Agriculture Research Institute, Tandojam Pakistan located at 25º25’60’N 68º31’ 60E during 2008 and 2009. The experimental design was thrice replicated randomized complete block design (RCBD), having net plot size 4m x 3m = 12 m^2 and ten treatments includes, T_1. Weedy check (full season), T_2. Sorghum mulch (soil incorporated) at 6 Mg ha^{-1}, T_3. Sorghum mulch (soil incorporated) at 12 Mg. ha^{-1}, T_4. Sorghum mulch (surface cover) at 6 Mg ha^{-1}, T_5. Sorghum mulch (surface cover) at 12 Mg ha^{-1}, T_6. Sorghum water extract concentrations (1 spray) at 10 L ha^{-1} at 4 WAS, T_7. Sorghum water extract concentrations (2 sprays) at 10 L ha^{-1} at 4 and 6 weeks after sowing, T_8. Sorghum water extract concentrations (1 spray) at 15 L ha^{-1} at 4 weeks after sowing, T_9. Sorghum water extract concentrations (2 sprays) at 15 L ha^{-1} at 4 and 6 weeks after sowing and T_{10}. Hand weeding (two times) at 4 and 6 weeks after sowing. Before experiment the soil was analyzed, report showed that the soil was clay loam, non-saline, low in organic matter (0.57-0.59%), available phosphorus (3.10-3.40 mg kg^{-1}) but high in exchangeable potassium (166 mg kg^{-1}), proper land preparation operations were performed for achieving good seed bed and equal distribution of seed, fertilizer and irrigation. The sowing was done with hand drill on 15th November in both years. Fertilizer dose at the rate of 134-67-67 NPK kg ha^{-1} was applied in the form of urea into two split doses and entire dose of P_2O_5 phosphorus and potash at the time of seed bed preparation. Wheat variety Imdad-2005 at the seed rate of 125 kg ha^{-1} was sown with single coulter hand drill in rows 22.5 cm apart. Data on weeds, growth and yield parameters of wheat crop was recorded accordingly. Sorghum organic mulch and allelochemical concentration prepared by the method as sorghum plants were harvested at maturity excluding grains which were sun dried and chopped with electric fodder cutter into 2 cm pieces. Chopped plants material were soil incorporated to a depth of 3-5 cm at the time of sowing and sorghum whole plants kept on soil as surface cover mulch. In case of preparation of concentrations, the sorghum plants were chopped and soaked in deionized water in 1:10 (1 kilogram sorghum in 10 L of water) for 24 hours at room temperature to prepare sorghum water extract. The sorghum water extract was obtained by filtering the mixture through a screen with muslin cloth. The volume of filtrate was reduced 20 times by continuously boiling to prepare concentrates of sorghum water extract as method adopted by Cheema *et al*., 2000). The weed control (WC) % was calculated by the following formula:

$$\text{WC (\%)} = \frac{\text{Weed density (m}^{-2}\text{) of weedy check} - \text{Weed density (m}^{-2}\text{) of given treatment}}{\text{Weed density (m}^{-2}\text{) of weedy check}} \times 100$$

3. RESULTS

Statistical analysis

The collected data was subjected to analysis of variance (ANOVA) technique using Statistix 8.1 computer software (Statistix, 2006). The least significant difference (LSD) test was applied to compare treatment means superiority at 5% probability level.

Table 1. Weed flora of wheat in the experimental field

Local Name	**English Name**	**Botanical Name**	**Weed frequency (%)**
Jhil	Lamb's quarters	*Chenopodium album*	8
Sinjh	White sweet clover	*Melilotus alba*	7
Jangli palak	Dock broad leaf	*Rumex dentatus*	4
Bili booti	Red chick weed	*Anagallis arvensis*	5
Naro	Bind weed	*Convolvulus arvensis*	10
Bhatar	Milk weed	*Launaea nudicauls*	2
Kabah	Purple nutsedge	*Cyprus rotundus*	11
Jangli jai	Wild oat	*Avena fatua*	25
Dhank	Little seed canary grass	*Phalaris minor*	22
Chhabar	Bermuda grass	*Cynodon dactylon*	6

Impact of mulches and concentrations on weeds of wheat

Sorghum mulches surface cover, soil incorporated and sorghum water extracts highly significantly affect weeds in wheat crop i.e total weeds, weed density, weed control %, fresh weed biomass and dry weed biomass respectively. Weeds are effectively suppressed by soil surface cover mulches, soil incorporated at 12 Mg ha^{-1} and sorghum water extract concentrations (2 sprays) at 15 L ha^{-1} at 4 and 6 weeks after sowing as stated by Cheema and Khaliq (2000) also sprayed water extract of matured sorghum and found reduced weed biomass by 35-40% respectively. However, hand weeding also proved better over weedy check or control plots.

Table 2. Allelopathic impact of sorghum mulches and concentrations on weeds

Treatments	Weed density (m^{-2})	Weed fresh biomass ($g\ m^{-2}$)	Weed dry biomass ($g\ m^{-2}$)	Weed control (%)
Weedy check (full season)	37.50 a	482.7 a	72.17 a	00.00 g
Sorg. mulch (S.I) at 6 Mg ha^{-1}	21.17 c	315.7 c	53.83 bc	43.54 e
Sorg. mulch (S.I) at 12 Mg ha^{-1}	8.33 e	79.33 e	22.67 e	77.86 b
Sorg. mulch (S.C) at 6 Mg ha^{-1}	25.67 b	351.2 bc	55.33 b	31.54 f
Sorg. mulch (S.C) at 12 Mg ha^{-1}	16.00 d	207.3 d	37.17 d	57.33 d
Sorg. W.E. conc. (1 spray) at 10 L ha^{-1} at 4 WAS	22.83 bc	386.7 b	59.67 b	39.12 e
Sorg. W.E. conc. (2 spray) at 10 L ha^{-1} at 4 & 6 WAS	14.17 d	215.8 d	39.50 d	62.21 c
Sorg. W.E. conc. (1 spray) at 15 L ha^{-1} at 4 WAS	14.50 d	293.3 c	47.00 c	61.33 c
Sorg. W.E. conc. (2 spray) at 15L ha^{-1} at 4 & 6 WAS	5.13 f	68.20 f	17.90 f	86.32 a
Hand weeding (two) at 4 and 6 WAS	9.500 e	126.3 e	25.17 e	74.66 b
SE	1.270	20.56	2.613	4.206
LSD (5%)	3.635	58.86	7.480	12.04

Sorg. = sorghum, Mg = mega gram, S.I = soil incorporation, S.C = surface cover, W.E = water extract, Conc. = concentrations, WAS = weeks after sowing. Each value is a mean of three replications; values followed by different letters are significantly different at $P \leq 0.05$.

Effect of mulches and concentrations on growth and yield of wheat

The wheat crop traits are highly significantly influenced by various sorghum mulch and concentrations. The traits were plant height, spike length, grains spike^{-1}, grain wt. spike^{-1}, spikes m^{-2}, biological yield, grain yield and harvest index % age. Many researchers stated that mulch increasing wheat yield is due to soil and water conservation, improved soil physical and chemical properties, and enhanced soil biological activity (Ramakrishna *et al*., 2006) and Cheema and Khaliq (2000) reported that water extract spray reduced weed biomass by 35-40% and increased wheat yield by 10-21%. However it is proved by the present results that sorghum mulches and sorghum allelochemical concentrations remained superior in all wheat traits as compared to hand weeding and weedy check or control.

Table 3. Growth and yield of wheat in response to weed suppression through allelopathic mulches and concentrations of sorghum

Treatments	Plant height (cm)	Grains spike^{-1}	Seed index (1000-grain wt., g)	Grain yield (kg ha^{-1})
Weedy check (full season)	86.20 f	54.21 f	35.94 e	4.398 g
Sorg. mulch (S.I) at 6 Mg ha^{-1}	91.47 de	61.42 cde	43.29 bcd	6.132 de
Sorg. mulch (S.I) at 12 Mg ha^{-1}	95.28 ab	66.27 ab	46.70 a	7.493 a
Sorg. mulch (S.C) at 6 Mg ha^{-1}	93.03 cd	57.88 e	41.10 d	5.308 f
Sorg. mulch (S.C) at 12 Mg ha^{-1}	92.57 cd	62.57 bcd	43.33 bcd	6.270 cd
Sorg. W.E. conc. (1 spray) at 10 L ha^{-1} at 4 WAS	90.45 e	58.97 de	42.47 cd	5.742 e
Sorg. W.E. conc. (2 spray) at 10 L ha^{-1} at 4 & 6 WAS	94.27 bc	64.18 abc	45.17 ab	6.633 bc
Sorg. W.E. conc. (1 spray) at 15 L ha^{-1} at 4 WAS	93.80 bc	62.77 bc	45.00 abc	6.575 c
Sorg. W.E. conc. (2 spray) at 15L ha^{-1} at 4 & 6 WAS	96.50 a	67.76 a	47.15 a	7.642 a
Hand weeding (two) at 4 and 6 WAS	94.52 abc	65.81 ab	46.51 a	7.045 b
SE	0.6661	1.219	0.8339	0.1449
LSD (5%)	1.907	3.489	2.387	0.4149

Sorg. = sorghum, Mg = mega gram, S.I = soil incorporation, S.C = surface cover, W.E = water extract, Conc. = concentrations, WAS = weeks after sowing. Each value is a mean of three replications; values followed by different letters are significantly different at $P \leq 0.05$.

Effect of mulches and concentrations on physiological traits of wheat

Wheat physiological traits are highly significantly affected by various sorghum organic mulches. Wheat traits were leaf area, leaf area index, dry matter production at 3rd leaf stage, flag leaf stage and at physiological maturity stage and crop growth rate. All sorghum organic treatments including mulches as well as water extract concentrations enhanced to various wheat physiological parameters by applying sorghum organic mulches soil incorporated as well as whole sorghum plant surface cover mulch. However, hand weeding remained superior over weedy check or untreated control plots. The findings of Rahman *et al*. (2005) also agreed with findings that crops straw mulch and allelochemical effects on crops growth.

Table 4. Physiological traits of wheat in response to weed suppression through allelopathic mulches and concentrations of sorghum

Treatments	Leaf area index (%)	Crop growth rate (g m^{-2} day^{-1})	Dry matter (g m^{-2}) at 3^{rd} leaf	Dry matter (g m^{-2}) at Flag leaf
Weedy check (full season)	1.227 h	4.906 h	63.67 b	0.3633 g
Sorg. mulch (S.I) at 6 Mg ha^{-1}	1.645 g	9.300 ef	69.50 ab	0.6373 def
Sorg. mulch (S.I) at 12 Mg ha^{-1}	2.333 b	13.45 a	77.67 a	0.8987 ab
Sorg. mulch (S.C) at 6 Mg ha^{-1}	1.670 g	7.945 g	66.67 b	0.5520 f
Sorg. mulch (S.C) at 12 Mg ha^{-1}	1.837 f	10.21 de	72.33 ab	0.6960 c-f
Sorg. W.E. conc. (1 spray) at 10 L ha^{-1} at 4 WAS	1.648 g	8.603 fg	66.50 b	0.5920 ef
Sorg. W.E. conc. (2 spray) at 10 L ha^{-1} at 4 & 6 WAS	2.272 c	11.49 bc	69.50 ab	0.7707 a-d
Sorg. W.E. conc. (1 spray) at 15 L ha^{-1} at 4 WAS	2.025 e	11.09 cd	69.83 ab	0.7467 b-e
Sorg. W.E. conc. (2 spray) at 15L ha^{-1} at 4 & 6 WAS	2.392 a	13.93 a	72.50 ab	0.9227 a
Hand weeding (two) at 4 and 6 WAS	2.142 d	12.42 b	71.17 ab	0.8293 abc
SE	0.01826	0.3502	3.144	0.05323
LSD (5%)	0.05227	1.003	59.31	0.1524

Sorg. = sorghum, Mg = mega gram, S.I = soil incorporation, S.C = surface cover, W.E = water extract, Conc. = concentrations, WAS = weeks after sowing. Each value is a mean of three replications; values followed by different letters are significantly different at $P \leq 0.05$.

4. DISCUSSIONS

Rapidly increasing population is world's challenge, for which agriculture researchers especially agronomists trying to fulfill the human food requirements by controlling yield limiting constraints particularly post sowing losses, this research also is a step towards yield increasing approaches. Weeds are major constraints to agriculture production. Many research findings indicate that more than 30% losses to crop yield occur due to weeds and further research also indicated the soil degradation and economic problems to control weeds. This research is concerned with environmentally safe organic agriculture in which use of plants against plant to control weeds. Sorghum crop used as tool for controlling weeds by various ways i.e. crop organic mulches surface cover and soil incorporated as well as crop water extract concentrations to control weeds. This research proved that soil incorporated, surface cover mulches and different water extract concentrations of sorghum effectively influenced on suppression of various weed species hence remarkably yield also increased due to above mention research done. According to Khan *et al.* (2002) weeds adversely influence on crops yield among many factors, Weeds affect the crop growth due to competition, allelopathy and by providing habitat for other harmful organisms. Allelopathy is a novel approach to keep the environment safe and to develop sustainable agriculture (Yongqing, 2005). In general weeds interfere to crops as compete for resources and allelopathy is key tool can be used for suppressing weeds. Researchers indicated that weeds can reduce wheat yield by 17-50% (Abbas *et al.* 2010) and a research proved that 37% wheat grain yield can be increased y properly controlling weeds (Khan *et al.*, 2000). In this study, sorghum organic mulches surface cover and sorghum chopped material soil incorporated and sorghum water extract concentrations effectively influence on weeds suppression and positively response in various wheat growth and yield traits.

Allelopathic effect of sorghum mulches and water extract concentrations

Sorghum water extract concentrations more effectively influenced than soil incorporated mulch, this finding confirmed by Cheema *et al.*, (2000) who reported that sorghum residues reduced normal weed population by 95%. The influence of sorghum mulches surface cover on weed suppression also indicated by Narwal (2000) who stated that sorghum–sudangrass hybrids suppress many annual weeds.

Effect of sorghum mulches and water extract concentrations on wheat growth and yield traits

The wheat crop traits are highly significantly influenced by various sorghum mulch and concentrations. The traits were plant height, spike length, grains spike^{-1}, grain weight spike^{-1}, spikes m^{-2}, biological yield, grain yield, and harvest index %. Many researchers stated that mulch increasing wheat yield due to soil and water conservation, improved soil physical and chemical properties, and enhanced soil biological activity (Ramakrishna *et al.*, 2006) and Cheema and Khaliq (2000) reported that water extract spray reduced weed biomass by 35-40% and increased wheat yield by 10-21%. However, it is proved by the present results that sorghum mulches and sorghum water extract concentrations remained superior in all wheat traits as compared to hand weeding and weedy check for full season.

Effect of sorghum mulches and water extract concentrations on weed suppression

Sorghum mulches surface cover, soil incorporated and sorghum water extract concentrations highly significantly affect weeds in wheat crop i.e weed density, weed control %, fresh weed biomass and dry weed biomass respectively. Weeds are effectively suppressed by soil surface cover mulches, soil incorporated at 12 Mg ha^{-1} and sorghum water extract concentrations (2 sprays) at 15 L ha^{-1} at 4 and 6 weeks after sowing as stated by Cheema and Khaliq (2000) also sprayed water extract concentration of matured sorghum and found reduced weed biomass by 35-40% respectively. However, hand weeding also proved better over weedy check or untreated plots. The findings of Einhelling and Rasmussen (1989) pointed out that suppressive effects of sorghum were primarily on broad-leaved weeds.

Effect of sorghum mulches and sorghum water extract on physiological traits

Wheat physiological traits are highly significantly affected by various sorghum mulches. Wheat traits were leaf area, leaf area index, and dry matter production at 3rd. leaf stage, flag leaf stage and at physiological maturity stage and crop growth rate. All sorghum organic treatments including mulches as well as water extract concentrations enhanced to various wheat physiological parameters by applying sorghum mulches (soil incorporated) as well as whole sorghum plant (surface cover) mulch. However, hand weeding remained superior over weedy check or untreated plots. The findings of Rahman *et al*. (2005) also agreed with findings that crops straw mulch and allelochemical effects on crops growth.

5. CONCLUSIONS

After detailed investigation, it is concluded that the water extract concentrations of sorghum at 15 L ha^{-1} (2 sprays) at 4 and 6 weeks after sowing was found efficient allelochemical application to suppress density and growth of weeds and also enhanced maximum agronomic traits, physiological growth, yield ha^{-1}. Organic mulches of sorghum application methods soil incorporation at 12 Mg ha^{-1} reduced density and growth of weeds as well as observed better for high yield of wheat. Hand weeding (two times) at 4 and 6 weeks after sowing recorded minimum density and growth of weeds and was found better for obtaining higher yield of wheat. The water extract concentrations of sorghum at 10 L ha^{-1} (2 sprays) at 4 and 6 weeks after sowing had slightly better over organic mulches application as surface cover at 12 Mg ha^{-1}. The application of organic mulches of sorghum as a surface cover at 12 Mg ha^{-1} had 3rd rank to control weeds and enhance crop growth and yield. The sorghum soil incorporation at 12 Mg ha^{-1} x5 irrigations established maximum suppression of weeds and also found superior for achieving highest yield of wheat. Wheat irrigated with 5 irrigations recorded better growth and yield as compared to rest of irrigation frequencies. Soil incorporation of sorghum was found expensive. Water extract concentrations of sorghum should be applied at the rate of 15 L ha^{-1} (2 sprays) at 4 and 6 weeks after sowing as economical and time saving approach for weed suppression and increased yield of wheat. Hand weeding is uneconomical due to higher labor charges.

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