WEED MANAGEMENT AND YIELD IMPROVEMENT IN COTTON THROUGH ALLELOPATHIC MULCHES OF SORGHUM AND SUNFLOWER STRAW

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ABSTRACT

Weeds are the major biotic constraints reducing crop yield. The injudicious and indiscriminate use of herbicides has created environmental pollution and human health hazards. Manual methods are expensive. Allelopathy has emerged as an environment-friendly and effective approach for weed management in field crops. Sorghum and sunflower plants possess many allelopathic compounds with phytotoxic potential. Weeds can be controlled effectively and use of herbicides can be minimized through utilizing allelopathic properties of such plants. A field study was carried out at Cotton Section, Agriculture Research Institute, Tandojam Pakistan during *kharif* (summer) 2010 and 2011. The experimental treatments comprised of mulches of sorghum and sunflower straw (10 and 15 t ha^{-1}, respectively, interculturing twice (at 30 and 60 days after sowing: DAS), herbicide Dual Gold 960-EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} and control (weedy check). The results indicated that all the levels of sorghum and sunflower mulches resulted in substantial suppression of weeds and enhanced seed cotton yield as compared to control (weedy check). Sunflower and sorghum straw as mulch (15 t ha^{-1}) exhibited strong allelopathic properties with efficient weed control (67.5 and 67.0 %, respectively), seedcotton yield (3953.6 and 3938.3 kg ha^{-1}, respectively) and net benefits (Rs. 222090 and Rs. 176527 ha^{-1}, respectively). Interculturing twice resulted in 69.0 % weed control with 3971 kg ha^{-1} seedcotton yield and Rs. 211390 ha^{-1} net benefit as compared to control. Therefore, use of sunflower straw as mulch was found economical for weed control and enhancing cotton yield whereas, sorghum mulch and interculturing were found less or uneconomical due to highest costs involved in both treatments.

Key words: Allelopathy, cotton, mulches, sorghum and sunflower straw, weeds, yield.

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the important *kharif* season crop being grown in Pakistan for fibre and edible oil. This crop provides fibre to textile industry for manufacture of cloth and cotton seed to oil industry for production of edible oil. It earns money through foreign exchange and has big share in Pakistan's economy. Despite being important crop of Pakistan average yield of cotton is very low (773 kg ha^{-1}) as compared to potential yield (1200 kg ha^{-1}) and obtained in advanced cotton growing countries of the world (Anonymous, 2014). The reasons for lower yield of cotton in our conditions are many. Among those, weed interference is considered as major and threatening one (Aladakatti *et al.*, 2011). The sowing of cotton in wide inter-row spacing and initial slow growth character of cotton favours germination and growth of weeds rapidly. Many broad and narrow leaf annual and perennial weeds infest cotton crop. The main purpose for controlling weeds is to create an environment with least expenditure in which crop plants may grow and develop luxuriously and ultimately increase crop yield per unit area (Jabran *et al*., 2010).

The control of weeds through manual methods involve huge labor which is not available easily, if available it is very expensive and time consuming. In order to save the money and time, farmers apply herbicides for quick and effective control of weeds. Due to having no proper knowhow of handling the toxic chemicals and proper use of herbicides health hazards are caused. This situation has drawn the attention of agriculture scientists and researcher to search for alternative methods which are effective for weed control, environmentally safe, cheap and sustainable (Tauseef *et al*., 2012; Afridi and Khan 2014; 2015).

Allelopathy is the direct or indirect inhibitory or promontory effect of one plant species on neighbouring plants of another species through releasing chemical compounds (allelochemicals) into the plant rhizosphere. When allelochemicals are released in greater quantity, negative effects occur on nearby plants and if the concentration of these chemicals is less, positive effects on the growth and development of other plant species growing in the vicinity have been observed (Farooq *et al*., 2011). Many allelopathic compounds have been identified in both sorghum and sunflower in several bioassays. Sorgoleone, an allelochemical identified from sorghum has demonstrated remarkable phytotoxicity in numerous plant growths assays (Duke *et al*., 2007). Sunflower is reported having allelopathic suppressing influences on weeds as stated by earlier workers like Bogatek *et al.* (2006). Mulching is the covering of land surface in between two rows of crop with some trash material like whole plant, plant leaves, straw, plastic sheets, saw dust etc (Alsaadawi *et al*., 2011). The dependence on herbicides could be minimized by using mulches of allelopathic crops (Khaliq *et al.,* 2011b).

MATERIAL AND METHODS

A field study was carried out at Agriculture Research Institute, Tandojam, Sindh, Pakistan during *kharif* 2010 and 2011. The treatments consisted of: sorghum mulch @ 10 t ha^{-1}, sorghum mulch @15 t ha^{-1}, sunflower mulch @10 t ha^{-1}, sunflower mulch @15 t ha^{-1}, interculturing twice (at 30 and 60 DAS), herbicide Dual Gold 960-EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} as pre-emergence and control (weedy check). The allelopathic crops straw as mulch was used immediately after sowing of cotton in between the rows. The seed of cotton variety Sindh-1 was sown with the help of single coulter drill on 1st May every year. The inter-row and intra-row spacings were maintained as 75 and 20 cm, respectively. The extra plants were thinned out at 25 DAS to maintain the spacing of 20 cm between plants. The land was ploughed with cultivator and planked for fine seedbed. The sub-channels and channels were prepared to irrigate the land properly. Nitrogen, phosphorus and potassium were applied in the form of Urea, DAP and SOP @ 115, 60 and 50 kg ha^{-1}, respectively. Full dose of DAP and SOP and 1/3rd of Urea were applied at the time of sowing. The remaining Urea was applied in two equal splits at 1st and 2nd irrigation. Keeping in view soil moisture content and climatic conditions, crop was 1st irrigated at 30 DAS while subsequent irrigations were applied at the interval of 15-20 days. As a whole, the crop was irrigated seven times. The data were gathered 90 DAS on weed density (m^{-2}), fresh weight (g m^{-2}) and dry weight (g m^{-2}). After counting weeds, they were cut at ground level with sharp sickle. The fresh weight was recorded immediately after cutting whereas, dry weight was recorded after drying. The weed control (WC) % was also determined by the following formula:

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

The data were also gathered on some of the important parameters of cotton like plant height (cm), sympodia per plant, opened bolls per plant, seed cotton weight per plant (g) and seedcotton yield (kg ha^{-1}). The 1st picking was performed when 50% bolls were opened while 2nd and 3rd pickings were carried out at the interval of 15 days between each picking.

Statistical analysis

The data were subjected to analysis of variance technique using Statistix 8.1 computer software. The Tukey's HSD test was applied to compare treatments superiority (Statistix, 2006).

RESULTS AND DISCUSSION

Weeds traits

The results (Table-1) showed that mulches of sorghum and sunflower straw as well as interculturing and herbicide treatments caused significant ($P<0.05$) inhibition of weeds as compared to control (weedy check). The lowest statistically equal ($P\geq0.05$) weed density (52.0, 54.9 and 55.4 m^{-2}), weed fresh weight (316.0, 330.1 and 334.3 g m^{-2}) and weed dry weight (142.2, 149.7 and 151.6 g m^{-2}) as well as highest weed control (69.0, 67.5 and 67.0 %) was recorded in interculturing twice (at 30 and 60 DAS), sunflower mulch @ 15 t ha^{-1} and sorghum mulch @ 15 t ha^{-1}, respectively. The herbicide Dual Gold 960-EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} ranked 4^{th} with 73.0 m^{-2} weed density, 448.2 weed fresh weight, 201.7 g m^{-2} weed dry weight and 56.5% weed control. The reduction in weed density authenticates the existence of allelopathic compounds in sorghum and sunflower straw with inhibitory effect. It also indicates that higher quantity of sorghum and sunflower straw mulches exhibited strong phytotoxic effects on weeds as against lower quantities. This suggested that more the sorghum and sunflower straw material mulched on the soil more was the weed suppression possibly due to better physical cover and more release of allelochemicals into the soil. The decline in weed density and weight may partially be attributed to the physical cover provided by the surface mulch and partially to the allelochemicals released by decomposition of sorghum and sunflower herbage. These results confirm the general effectiveness of sorghum and sunflower straw allelochemicals for controlling weeds. The allelopathic compounds like syringic acid, p-hydroxybenzoic acid, p-coumaric acid, protocateuic acid, vanillic acid, sorgoleone, gallic acid and benzoic acid have been isolated in sorghum (Narwal *et al*., 2005). So far more than 200 allelopathic compounds have been isolated in sunflower, among them major groups of allelochemicals flavonoids, terpenoids and phenolics are also included (Anjum and Bajwa, 2008). Earlier studies have suggested that surface mulch or soil incorporation of allelopathic crop herbage influences weed dynamics by inhibiting or delaying seed germination, reducing subsequent plant growth, consequently contributing to overall reduction in weed density and biomass (Khaliq *et al*., 2011b). Similarly, Birkett *et al*. (2001) revealed that phytotoxins are solubilized rapidly in crop residues and consequently suppress the emergence and subsequent seedling growth of weeds. These findings also support the work done by Alsaadawi *et al.* (2005) and Ashrafi *et al.*

(2008) who stated that decrease in density and dry biomass of weeds was due to presence of allelochemicals in sorghum and sunflower herbage.

Growth and yield parameters of cotton

The data shown in Table-2 revealed that various levels of sorghum and sunflower straw mulching as well as interculturing and herbicide treatments significantly improved growth and yield attributes of cotton in contrast to control (weedy check). Interculturing twice (at 30 and 60 DAS) resulted in maximum plant height (116.0 cm) more no. of sympodia (24.3 plant^{-1}), opened bolls (37.6 plant^{-1}) seedcotton weight plant^{-1} (110.9 g) and seedcotton yield (3971.4 kg ha^{-1}). Sunflower mulch (@15 t ha^{-1}) followed with 115.4 cm plant height, 23.9 sympodia plant^{-1}, 36.9 opened bolls plant^{-1}, 109.8 g seedcotton weight plant^{-1} and 3953.6 kg ha^{-1} seedcotton yield. Sorghum mulch (@15 t ha^{-1}) conferred 115.1 cm plant height, 23.8 sympodia plant^{-1}, 36.4 opened bolls plant^{-1}, 109.4 g seedcotton weight plant^{-1} and 3938.3 kg ha^{-1} seedcotton yield. However, herbicide Dual Gold 960 EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} as pre-emergence was found fourth in enhancing cotton yield with 111.7 cm plant height, 21.6 sympodia plant^{-1}, 34.0 opened bolls plant^{-1}, 104.6 g seedcotton weight plant^{-1} and 3450.3 kg ha^{-1} seedcotton yield. Moreover, the careful perusal of data envisaged that sunflower mulch (@ 15 t ha^{-1}), sorghum mulch (@ 15 t ha^{-1}) and interculturing twice were statistically similar ($P \geq 0.05$) with each other for almost all the traits studied, particularly seedcotton yield. The improvement in yield of cotton may be attributed to the fact that allelopathic crops mulch significantly suppressed weeds, conserved moisture and nutrients resulting in less competition between crop plants and weeds for growth resources and these conserved resources were fully utilized by cotton crop for proper growth and development. The better growth and yield of cotton crop in response to higher doses of sunflower and sorghum straw mulches indicated that more the material added on the soil more was the weed suppression and more availability of growth resources to cotton plants. These results are supported by the findings of Cheema *et al*. (2000) who suggested that allelochemicals present in sorghum stalk suppressed weeds and exerted significant positive effects on bolls plant^{-1} and increased seed cotton yield by 59% over control. As mulching of allelopathic crops suppressed weeds effectively wherein plant height of cotton crop were higher which resulted in increased sympodia plant^{-1}, opened bolls plant^{-1}, seed cotton weight plant^{-1} and ultimately the seed cotton yield. The results are in conformity with the results of Mahmood (2009) who reported that sunflower and sorghum residues inhibited weeds more effectively and resultantly maize growth, yield contributing characters and yield was enhanced.

Economic analysis

Sunflower and sorghum straw mulches demonstrated strong allelopathic action, caused marked inhibition of weeds and enhanced seedcotton yield considerably in comparison with control-weed check (Table-3). Application of sunflower mulch (@ 15 t ha^{-1}) gave maximum net benefit of Rs. 222090 ha^{-1}, followed by interculturing twice (at 30 and 60 DAS) with Rs. 211390 ha^{-1}. Herbicide (Dual Gold), sunflower mulch (@10 t ha^{-1}), sorghum mulch (@15 t ha^{-1}) and sorghum mulch (@10 t ha^{-1}) produced respective net benefits of Rs. 190781, 181463, 176527 and 157139 ha^{-1} as compared to the lowest net benefit of Rs. 114321 ha^{-1} obtained with control treatment. The results further suggested that sorghum mulch and interculturing were less economical. The results of this study are in concurrence with those of Khaliq *et al*. (2011 a & b) who have reported higher net monetary benefits of allelopathic plant mulches, particularly sunflower for weed control and crop yield improvement.

CONCLUSION

The results concluded that sunflower mulch (@ 15 t ha^{-1}) controlled weeds and produced seedcotton yield at par with sorghum mulch (@ 15 t ha^{-1}) and interculturing twice (at 30 and 60 DAS) at one side but generated more net monetary benefits at other side as compared to foregoing treatments. Sorghum mulch and interculturing were found uneconomical due to higher costs of herbage and labour, respectively. Hence, it was inferred from the results that for effective weed control through mulching in cotton, sunflower herbage may preferably be applied as cheapest natural and eco-friendly source of weed control.

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Table-1. Weeds dynamics under the allelopathic influence of sorghum and sunflower straw as mulch

Treatments	Weed density (m^{-2})	Weed fresh weight ($g\ m^{-2}$)	Weed dry weight ($g\ m^{-2}$)	Weed control (%)
Control (weedy check)	167.7 a	1177.6 a	529.9 a	0.0 d
Interculturing twice (at 30 and 60 DAS)	52.0 d	316.0 c	142.2 d	69.0 a
Dual Gold 960 EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} as pre-emergence	73.0 c	448.2 b	201.7 b	56.5 b
Sorghum mulch (@10 t ha^{-1})	75.2 c	464.1 b	172.8 c	55.2 b
Sorghum mulch (@15 t ha^{-1})	55.4 d	334.3 c	151.6 d	67.0 a
Sunflower mulch (@10 t ha^{-1})	80.7 b	470.0 b	211.6 b	51.9 c
Sunflower mulch (@ 15 t ha^{-1})	54.9 d	330.1 c	149.7 d	67.5 a
$HSD_{0.05}$	4.128	22.74	10.37	2.76

Means sharing different letters are significant at 0.05 probability level.

Table 2. Growth and yield of cotton as influenced by sorghum and sunflower straw as mulch

Treatments	Plant height (cm)	Sympodia plant^{-1}	Opened bolls plant^{-1}	Seedcotton weight plant^{-1} (g)	Seedcotton yield (kg ha^{-1})
Control (weedy check)	106.3 c	17.5 e	25.9 d	83.7 d	2032.4 e
Interculturing twice (at 30 and 60 DAS)	116.0 a	24.3 a	37.6 a	110.9 a	3971.4 a
Dual Gold 960 EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} as pre-emergence	111.7 ab	21.6 b	34.0 b	104.6 b	3450.3 b
Sorghum mulch (@10 t ha^{-1})	107.5 bc	20.1 c	31.0 c	102.4 c	3326.9 c
Sorghum mulch (@15 t ha^{-1})	115.1 a	23.8 a	36.4 a	109.4 a	3938.3 a
Sunflower mulch (@10 t ha^{-1})	106.6 c	19.2 d	29.9 c	101.7 c	3261.6 d
Sunflower mulch (@15 t ha^{-1})	115.4 a	23.9 a	36.9 a	109.8 a	3953.6 a
S.E ±	2.28	0.35	0.77	1.00	19.89
$HSD_{0.05}$	4.98	0.76	1.67	2.19	43.33

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Table 3. Economics of sorghum and sunflower straw as mulch for weed control in cotton

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Remarks
Seed cotton yield	2032	3971	3450	3326	3938	3261	3953	kg ha^{-1}
Adjusted yield	1829	3574	3105	2994	3544	2935	3558	10% less than actual (kg ha^{-1})
Seedcotton value	114321	223390	194081	187139	221527	183463	222390	Rs. 2500 (40 kg^{-1})
Herbicides cost	-	-	2500	-	-	-	-	Rs. 1000 L^{-1}
Interculturing cost (Twice)	-	12000	-	-	-	-	-	Rs. 300 per Labor, (20+20 persons ha^{-1})
Mulching cost				30000	45000	2000	3000	Rs. 3000 ton^{-1} (Sorghum) Rs. 200 ton^{-1} (Sunflower)
Labor charges (spray)	-	-	600	-	-	-	-	-
Sprayer rent	-	-	200	-	-	-	-	-
Cost that vary	0.00	12000	3300	30000	45000	2000	3000	-
Net benefits	114321	211390	190781	157139	176527	181463	222090	-

T_1 = Control (weedy check), T_2 = Interculturing twice (at 30 and 60 DAS), T_3 = Dual Gold 960 EC (S-metolachlor) @ 2.4 kg *a.i.* ha^{-1} as pre-emergence, T_4 = Sorghum mulch (10 t ha^{-1}), T_5 = Sorghum mulch (15 t ha^{-1}), T_6 = Sunflower mulch (10 t ha^{-1}) and T_7 = Sunflower mulch (15 t ha^{-1})

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