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Weed control in wheat using sorghum residues and less herbicide

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ABSTRACT

A two-year field trial was conducted to test the responses of weed and wheat crop to different rates (3.5, 5.3 and 7.6 t ha^{-1}) of *Sorghum bicolor* L. (Moench) residues alone or in combination with 50% rate (160 g ha^{-1}) of mesosulfuron and iodosulfuron as the chevalier herbicide. Weedy check, 50% dose and full dose of herbicide treatments were included for comparison. All treatments significantly reduced the weed population and their dry weight over weedy check treatment in both years (2010 and 2011). However, plots treated with 50% rate of herbicide and amended with sorghum residues significantly suppressed weed density and dry biomass than when the residue or reduced herbicide rates were applied alone. Application of chevalier herbicide at 50% rate in plots amended with sorghum residue at rates 3.5 and 5.3 t ha^{-1} resulted in similar yield as with the full herbicide dose (320 g ha^{-1}) treatment; while the higher residues rate (7.6 t ha^{-1}) alone or with 50% herbicide dose decreased the crop yield. The increase in yield was apparently due to increase in number of spikes per unit area. Biochemical analysis revealed the presence of higher total phenolics in sorghum amended field plots than control plots soil. Periodic data revealed that maximum quantities of phenolics coincided with the period of maximum suppressive activity against weeds under field condition, which explain the activity of phytotoxins on weed suppression. Integration of sorghum residues at 3.5 and 5.3 t ha^{-1} with half dose of chevalier herbicide rate provided weed suppression without compromising yield. The other advantages of this method were improvement of soil physical-chemical and physical properties.

Key words: Allelopathy, chevalier herbicide, phenolics, sorghum {*Sorghum bicolor* L. (Moench)} residues, wheat (*Triticum aestivum* L.), weeds.

INTRODUCTION

Weed management in field crops has been a serious problem in many countries. Potential yield reductions caused by uncontrolled weed growth throughout growing season have been estimated to be 45 to 95%, depending on crop species, weed species, weed densities, and ecological factors (6,18). Therefore, weed management is a key element of most agricultural systems (22). Application of herbicides has been a major practice enabling the intensification of agriculture in past decades and about three million tons of herbicides per year are used in most agricultural systems (24). However continuous use of synthetic herbicides has increased the numbers of herbicides resistant weed biotypes, posing sever threat to the environment and causing health risks. These causes have

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attracted the attention of researchers to search for new approach of weed control which may be inexpensive, easy to use and helpful in maintaining the ecosystem sustainability (1,14). Allelopathy holds a great prospect for meeting some of those demands and may be more readily applicable in agroecosystems. Different strategies have been suggested to use allelopathy for weed control including crop rotation and intercropping, cover crop or smother crop, crop residues as mulch or incorporated in soil and plant water extracts. However, of all possible strategies, allelopathic crop residues is the most successful, effective and readily available (8,14,20).

Sorghum crop residues are inhibitory allelopathic effects on crops and weeds (1,15,16). However, in most case, the inhibitory potential of the residues was below the efficacy of herbicides (26). Therefore additional work is required to increase the suppressive efficacy of residues in order to reduce the reliance on herbicides. Bhowmik and Inderjit (9) suggested that herbicides applied along with allelopathic products could have complementary interaction. Cheema *et al*. (15) were able to reduce the herbicide rate for weed control in different crops through tank mixing of water extract of sorghum. Likewise, allelopathic crop residues combined with lower rates of herbicides had weed suppression similar to that achieved by the label rate of herbicides in field crops (4,5). Nonetheless, information concerning the potential of combined use of sorghum residues with lower rates of herbicides for weed management in wheat is not available. The present study was, therefore, conducted to test the combined effect of allelopathic sorghum residues to with lower rate of chevalier herbicide with aim of reducing input of chemical herbicide in agricultural ecosystem.

MATERIALS AND METHODS

The experiment was conducted at Research Farm of Field Crop Department, College of Agriculture, Baghdad University, Baghdad, Iraq (33.2 º N latitude and 44.22 ºE longitude, 34.1 m above sea level). The soil was calcareous clay loam [organic carbon, pH and electrical conductivity (EC) equal to 0.8%, 7.8 and 3.0 dS m^{-1}, respectively]. Average annual rainfall is < 50 mm and day/night temperatures during the growing season were 15-25 / 5-10 ºC. Seeds of sorghum *cv*. Enkath and wheat *cv*. Abu-Grab were obtained from Department of Crop Production of our University. Chevalier15 WG (Mesosulfuron, a.i + Iodosulfuron, a.i), a product of Bayer, was purchased locally.

Incorporation of sorghum residues

Field plots (5×6 m) were randomly made in July 2009 and 2010 in fields heavily infested with weeds. Sorghum seeds were sown in inter-row of 75 cm and inter-plant spacing of 5, 10 and 20 cm to achieve target plant densities of 6.6, 13.3 and 26.6 plants m^{-2}, respectively. A basal dose of 300 kg N ha^{-1} as urea (46% N) and phosphorus at 160 kg ha^{-1}as triple super phosphate (46% P_2O_5), were applied in each plot. Plots were irrigated as recommended for sorghum. At physiological maturity, panicles were removed then sorghum plants were cut at approximately 50 cm above the soil for livestock feeding. The remaining vegetative plant parts were left for drying for several days in their respective plots. These plots were then tilled twice with a disc plough to incorporate sorghum residues to a depth of 30 cm in the soil. Field measurements revealed that the plant densities of 6.6, 13.3 and 26. 6 plants $m^{-2,}$ after top removal of sorghum plants, resulted in sorghum residue application rate of about 3.5, 5.3 and 7.6 t ha^{-1} in both growing seasons.

Efficacy of sorghum residues in combination with herbicide on weeds and wheat

The plots of sorghum residues were divided into two plots measuring 3×5 m, while control plot was divided into three subplots measuring 2×5m. Nitrogen at 200 kg ha^{-1} and phosphorus at 100 kg ha^{-1} were applied in the form of urea (46%N) and triple super phosphate (46% P_2O_5), respectively. All the phosphorus and half nitrogen were applied at sowing time and the remaining half of nitrogen was added one month after sowing with irrigation. Wheat seeds were sown manually in 25 cm spaced rows in early December of both seasons at a rate of 120 kg ha^{-1}. All plots were irrigated immediately after sowing and subsequent irrigations were adjusted as per the climatic conditions and the crop. Treatments were: three sorghum residue rates (3.5, 5.3 and 7.6 t ha^{-1}) with and without half dose of chevalier herbicide (160 g ha^{-1}). Untreated control (weedy check), 50% and 100% full dose (320 g ha^{-1}) chevalier herbicide were conducted for comparison. The experiment was laid out in a randomized complete block design with three replications. At 50 days after sowing, chevalier doses were applied with a spraying volume of 200 L ha^{-1}, using a Knapsack hand sprayer fitted with T-Jet nozzle at a pressure of 207 k Pa. Weed density and biomass were recorded at 130 DAS from four randomly selected quadrates (50×50 cm) of each experimental plot. Dry weight of weeds was recorded after drying in an oven at 75°C for 72 h. Wheat crop was harvested and threshed manually from individual treatment plots. Grain yield and yield components (number of spikes per m^2, number of grains per spike and weight of 1000 grains) recorded following standard procedures at maturity of crop (150 and 155 DAS during first and second year of study, respectively). Data collected was analyzed by Fisher's analysis of variance technique. Least significance difference (LSD) test was applied at 0.05 probability level to compare treatment means (23).

Total phenolics in field

In first season, maximum weed suppression was observed in sorghum residues amended plots up to 60 days after sowing (DAS). To test if the reduction in weed growth was related to phytotoxic compounds released during decomposition of sorghum residues, soil samples were taken from plots amended with 7.6 t ha^{-1} and 0 t ha^{-1} (weedy check) at a depth of 30 cm at 14, 28, 42 and 58 DAS using soil Auger (40 x 20 cm dia.). The soils were mixed thoroughly, dried at room temperature for 3 days. Samples of 250 g dry soil were extracted separately in 250 ml distilled water by shaking for 24 h at 200 rpm (7). Soil suspensions were filtered through Whatman # 2 filter paper under vacuum. Folin-Denis (0.5 ml) and Na_2CO_3 (one ml) were added to one ml of soil water extract and left to stand for 30 min. Absorbance was determined at 750 nm (11). The total phenolic content was obtained by standard curve using different concentrations of ferulic acid.

RESULTS

Weed population and biomass

The experimental field was dominated by *Beta vulgaris* L., *Ammi majus* L. Click, *Daucus carota* L., *Silybum marianum* L. Gaerth, *Carthamus axyacantha* L. Gaerth, *Avena* *fatua* L. Click, *Lolium temulentum* L. Click and *Phalaris minor* Retz. Click. In both years of study, herbicides application and sorghum residues incorporated in soil suppressed the weed density and dry biomass (Table 1).

During 2010 season, incorporation sorghum residues at 3.5, 5.3 and 7.6 t ha^{-1} reduced weed density by 38, 28 and 20 % of control, respectively. The corresponding inhibition in weed dry biomass was 26, 26 and 20 % of control, respectively for these rates of sorghum residues. However, the differences in the reduction of weed density and weed biomass was not statistically significant among the residues rates with the exception of weeds number at lower rate of residues (3.5 t ha^{-1}) which recorded significantly higher reduction than the7.6 t ha^{-1} residue treatment. Application of label rate of chevalier significantly decreased the weed population and dry biomass. Reduced (50%) herbicide rate of chevalier furnished 21 and 38 % reduction in weed density and biomass as against 49 and 49% reduction realized with the label rate of this herbicide. However, the efficacy of reduced herbicide rate was modified by sorghum residue incorporation rates due to significant interaction between these two factors. Herbicide application at reduced (50%) rate to plots amended with test sorghum residues scored significantly higher reduction in weed density and biomass compared to the reduced herbicide rate when applied alone. Meanwhile, reduced herbicide (50 %) rate in combination with 3.5 and 5.3 t ha^{-1} sorghum residue rates scored statistically similar weed population and weed biomass suppression as was observed under sole application of the label rate.

During 2011, less weed burden in terms of density and dry biomass was observed; yet, the trend of suppression under the influence of herbicide and sorghum residues remained almost the same. Soil incorporation of sorghum residues at 3.5, 5.3 and 7.6 t ha^{-1} furnished 49, 25 and 24 % average reduction in weed density; while weed dry biomass was dropped by 41, 50 and 48 %, respectively. Reduced (50%) and label rate of chevalier gave 41 and 78 % reduction of average weed density and 25 and 87 % reduction of weed biomass respectively. The maximum reduction in weed density (87 %) and biomass (89 %) was again realized by 50% of herbicide label rate application to plots amended with 3.5 t ha^{-1} sorghum residues rate. Nonetheless, reduced herbicide rate along with all test sorghum residue rates recorded as good weed population and biomass suppression as was realized with label herbicide rate.

Wheat yield and yield components

Yield of wheat was higher in season 2011 than in season 2010, yet, the trend of positive influence of reduced rate of herbicide and sorghum residues on yield remained almost consistent across years (Tables 2 and 3) . Chevalier at 50% of its label rate accompanied with sorghum residues at 3.5 and 5.3 t ha^{-1} recorded grain yield statistically similar to that achieved when the label rate of this herbicide was applied alone during 2010 and 2011, respectively.

A non-significant herbicide× sorghum residues interaction was observed for number of grains per spike and weight of 1000 grains, whereas this interaction was significant for number of spikes during both years. Application of reduced rate of chevalier to plots amended with 3.5 and 5.3 produced greater number of spikes per m^2 that was statistically similar to that recorded by the label chevalier rate during both seasons.

Table 1. Effects of half label rate of chevalier herbicide in combination with different rates of sorghum residues on population density (plants m^{-2}) and dry weight biomass (g m^{-2}) of weeds in wheat

Treatments	2010		2011	
	Weed density	Weed biomass	Weed density	Weed biomass
	Reduction (%)			
Weedy check (Control)	0.0	0.0	0.0	0.0
Residues at 3.5t ha^{-1}	38.2	25.9	49.4	41.2
Residues at 5.3 t ha^{-1}	28.4	26.0	25.2	49.5
Residues at 7.6 t ha^{-1}	20.0	19.5	23.9	47.7
Chevalier (50% of Label rate)	21.0	37.5	41.4	24.8
Residues at 3.5t ha^{-1} +50% rate of chevalier	61.1	68.5	87.2	89.2
Residues at 5.3 t ha^{-1} +50% rate of chevalier	61.2	63.0	71.14	75.7
Residues 7.6 t ha^{-1} +50% rate of chevalier	54.3	59.9	54.8	77.6
Chevalier (Label rate)	49.3	49.2	78.2	87.3
LSD ≤ 0.05	14.9	14.3	28.1	20.2

Weed density and weed dry weight of untreated control (weedy check) were 401. 3 plants m^{-2} and 355.6 g m^{-2}, respectively in 2010, and 304.0 plants m^{-2} and 226.4 g m^{-2}, respectively in 2011.

Table 2. Effects of half label rate of chevalier herbicide in combination with different rates of sorghum residues on yield and yield components of wheat (Season 2010)

Treatments	Yield (t ha^{-1})	Yield components		
		No. of spikes m^{-2}	No. of grains $spike^{-1s}$	1000-grain weights (g)
Weedy check (Control)	3.8	270.0	56.2	30.7
Residues at 3.5t ha^{-1}	4.0	293.3	48.2	31.6
Residues at 5.3 t ha^{-1}	3.6	313.3	52.9	28.5
Residues at 7.6 t ha^{-1}	3.0	284.4	56.6	30.5
Chevalier (50% of Label rate)	4.3	303.3	56.1	29.6
Residues at 3.5t ha^{-1} +50% rate of chevalier	4.9	356.7	57.7	32.5
Residues at 5.3 t ha^{-1} +50% rate of chevalier	4.5	353.3	58.3	30.6
Residues 7.6 t ha^{-1} +50% rate of chevalier	4.2	316.7	53.4	32.0
Chevalier (Label rate)	4.9	346.7	51.5	32.1
LSD ≤ 0.05	0.5	56.9	NS	N S

Table 3 Effects of half label rate of chevalier herbicide in combination with different rates of sorghum residues on yield and yield components of wheat (Season 2011)

Treatments	Yield (t ha^{-1})	Yield components		
		No. of spikes m^{-2}	No. of grains $spike^{-1s}$	1000-grain weights (g)
Weedy check (Control)	4.7	368.9	52.4	33.0
Residues at 3.5t ha^{-1}	5.4	378.9	58.0	31.6
Residues at 5.3 t ha^{-1}	4.9	332.2	55.7	32.2
Residues at 7.6 t ha^{-1}	4.1	367.8	51.1	34.5
Chevalier (50% of Label rate)	4.9	356.7	51.1	32.2
Residues at 3.5t ha^{-1} +50% rate of chevalier	6.1	408.9	54.7	34.6
Residues at 5.3 t ha^{-1} +50% rate of chevalier	5.6	380.0	56.7	33.2
Residues 7.6 t ha^{-1} +50% rate of chevalier	4.9	354.4	54.6	33.7
Chevalier (Label rate)	5.9	408.9	49.8	33.4
LSD ≤ 0.05	0.5	31.8	NS	NS

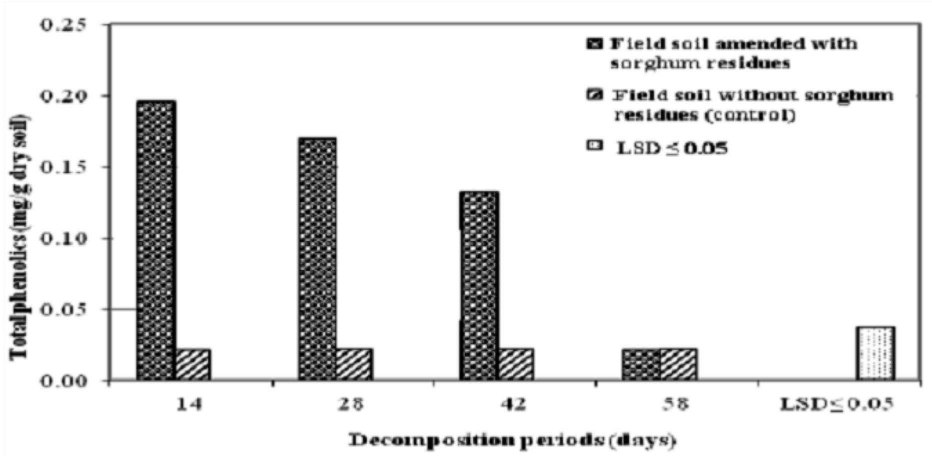

Figure 1. Total phenolics released in field soil amended with sorghum residues at 7.6 t ha^{-1} during different decomposition periods.

Phenolics dynamic in sorghum residues amended soil

Total phenolics in field soil significantly increased after incorporation of sorghum residue and reached the maximum concentration at 2 weeks and continued with higher amount during the subsequent decomposition periods until reached minimum concentration at the end of two months after sowing (Figure 1).

DISCUSSION

The data of the present work revealed that both herbicide and sorghum residues suppress weed growth. The substantial reduction of weed density and growth by sorghum residues could be due to the release of phytotoxic allelochemicals from the residues during their decomposition (10). Sorghum contains several phenolic allelochemicals responsible for the inhibitory activities against weeds (2,3,12,13,21). Most of these allelochemicals are reported to be water soluble and when imbibed by the germinating weed seeds, hamper their germination and subsequent seedling growth, thus contributing to overall decline in the density and vigor of weed community (17). However the reduction in weed population and dry weight of weeds appeared to be below the efficacy of herbicide and was in line with results observed earlier (4,13).

Chevalier herbicide is often used to control grass and broad- leaved weeds of wheat. The suppression effects are more obvious at the recommended dose than at the reduced (50%) rate. However, when herbicide at the reduced rate applied to plots amended with sorghum residues, the suppressions in most cases were statistically equal or even more effective than the label rate of chevalier during both years of study, indicating the possible reduction in herbicide rate by 50%. This result supports the objectives of the present study and confirmed the previous hypothesis proposed by Bhowmik and Inderjit (9) that a herbicide applied in combination with allelopathic conditions could enjoy a complementary interaction, and may help to minimize herbicide usage for weed management in field crops.

The improvement in wheat yield and number of spikes by herbicide and sorghum residues at 3.5 and 5.3 residues and weedy check treatments seems an outcome of reduced weed-crop competition for any of the growth factors which might have contributed to higher yields. It appears that weed suppression was directly translated into yield so that yield similar to that of the label rate of herbicide treatment was realized by all interaction treatments with the exception of the combination of higher residue rate (7.6 t ha^{-1}) with reduced herbicide rate where the yield was significantly reduced compared to sole application of label chevalier rate treatments. This may be attributed to the toxicity of higher rate of the sorghum residues against wheat. Weston et al. (26) indicated that the temporal nature of inhibition and/or stimulation provided by sorghum residues can successfully be applied to weed management in agroecosystems. They further mentioned that the inhibitory effect of sorghum residues on seed germination and growth of wheat under field conditions can be avoided by several methods such as decreasing the actual amount or rates of sorghum residues incorporated into the field soil.

It seems from chemical analysis that phenolics are released into rhizosphere by residue decomposition. No attempt was made to identify the phenolic compounds. However, our previous work (4) revealed the presence of phenolic acids namely syringic, vanillic, gallic, caffeic, *p*-coumaric, ferulic, *p*-hydroxybenzoic and protocatechuic acids from sorghum residue decomposition. The negative impacts of these allelochemicals on various physiological and biochemical plant processes have been reported elsewhere (19).

It is noteworthy to mention that the period indicating maximum quantities of phenolics coincided with the period in which maximum suppressive activity against weeds under field condition, which explains the activity of phenolics on weed suppression.

The present work concluded that sorghum residues can be used in conjunction with lower rate of herbicide to reduce input of herbicides in agro-ecosystems. Besides suppressing weeds, these residues could also have a positive bearing on the soil physical, chemical and biological characteristics of soil (8). Investigations into the allelopathic potential of different rates of other allelopathic crop residues along with different rates of herbicides under varying crop and environmental conditions need to be carried out before general conclusion can be made for particular crop or weed species.

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