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Impact of Crop Residue Management on Soil Properties and Crop Yield, in Irrigated Corn-Wheat Cropping System

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Authors' contributions

This work was carried out in collaboration between both authors. Author MAB designed the study, collected the data, and performed the statistical analysis. Author SA performed the laboratory analysis and wrote the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The main aim of this study was to determine the effects of residue management methods on the soil properties and crop yield in corn-wheat cropping system during four years research, and to introduce a proper residue management method for corn-wheat rotation in Fars province, Iran.
Study Design: The research was conducted in the form of a split-plot experimental design with three replications. Main-plots were wheat residue management with four levels, and corn residue with two levels was considered as subplots.
Place and Duration of Study: This study was conducted in Darab Research Station of Fars province, Iran from September 2005 to September 2009.
Methodology: This research was conducted in the form of a split plot experiment with the base of randomized complete block design (RCBD) with three replications in Darab Research Station of Fars province, Iran. Main-plots were wheat residue management methods including 1) shredding the residue using shredder and tilling the soil with moldboard plow (25 cm) and disk harrow; 2) shredding the residue using shredder and tilling the soil with chisel plow and rotivator; 3) retaining

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the crop residue on the soil surface without any tillage operation (no-till); and 4) burning the residue and tilling the soil with moldboard plow (25 cm) and disk harrow. Corn residue management methods including 1) stalk shredding using stalk shredder, burying the chopped stalk using moldboard plow (25 cm), and applying disk harrow; 2) burning residue (conventional method) were considered as sub-plots. Parameters consisting of bulk density, soil cone index, soil organic carbon, percentage of seed emergence, and crop yield were measured. Collected data were analyzed using SAS statistical software and Duncan's multiple range tests was used to compare the treatments means.

Results: Results indicated that shredding the residue by shredder and incorporation with soil decreased the soil bulk density and soil cone index. There was a significant difference between the burying crop residue and retaining the residue on the soil surface from the view point of soil bulk density and soil cone index. The percentage of seeds emerged, emergence rate index, and yield in shredding the residue by shredder along with applying chisel plow and rotivator had the highest amount because of the uniformity of residue distribution. After four years adding corn and wheat residue into the soil, the soil organic carbon increased for 13% and 10% in the residue management treatments and burning residue method, respectively.

Conclusion: The following conclusions could be drawn from the results of this study:

1. Adding shredded crop (corn and wheat) residue to the soil increased the soil organic carbon.
2. Soil bulk density and cone index (soil compaction) decreased by incorporating the chopped crop residue to the soil.
3. Adding chopped corn and wheat residue to the soil improved corn and wheat seed emergence and yield.

Keywords: Soil bulk density; soil cone index; seed emergence.

1. INTRODUCTION

Methods of crop residue management including burning residue, leaving residue on the soil surface, and removing residue from the field affect the soil properties and crop yield. Corn residue causes problems for planting next crop due to high volume. Residue management improves soil structure and fertility, and decreases soil erosion. Merdock et al. [1] reported that shredding corn residue caused high yield of next crop (wheat). Leaving the corn residues on the farm decreased the soil organic carbon up to 15% compared to burying residue using moldboard plow [2]. Retaining crop residue in corn-wheat cropping system in China increased wheat and corn yield compared to the removing crop residue treatment [3]. Residue burning reduces soil organic matter and fertility in different cropping systems compared to retaining crop residue on the soil [4]. Results of a research conducted in subarctic regions showed that retaining crop residues on the soil increases soil organic carbon compared to removing all residues each year [5].

Results of evaluating crop residue incorporation effects in corn-wheat or wheat-green gram cropping system on wheat grain and straw yield indicated that crop residues incorporation increased the wheat grain and straw yields for 31 and 38%, respectively. On the other hand, planting legume (green gram) before wheat crop increased wheat grain and straw yields for 89 and 105%, respectively [6]. Evaluating effect of crop residue type and amount on wheat yield and some soil properties revealed that incorporation of all crop residues reduced wheat yield, and incorporation of 25% sunflower residues provided the highest soil organic carbon and soil nitrogen content [7]. Results of a research conducted by Bakht et al. [8] showed that planting wheat in crop residue increased wheat grain and straw yields. Results of evaluating wheat residue on corn seed emergence and yield indicated that planting corn in wheat residue increased corn seed emergence and yield [9].

Tillage methods also have remarkable effects on crop yield and soil properties. Results of previous research works on conservation tillage showed that soil bulk density was significantly affected by conservation tillage methods [10,11,12]. Evaluating effects of tillage methods and crop residue managements in rice-wheat cropping system in India showed that wheat direct seeding slightly increased soil bulk density compared to the reduced tillage [13]. Results of comparing no-till and conventional tillage method in a silty-clay soil texture indicated that no-till treatment increased soil organic matter for 100%, but soil bulk density and penetration resistance were not affected by the tillage methods [14]. According to the results of a research conducted in Fars province, Iran in corn -wheat cropping system, the difference between soil bulk densities of conservation and conventional tillage methods was significant from the beginning up to the middle of growth season; whereas, there was no significant difference between soil bulk density of different tillage methods from the middle up to the end of crop growth season [15]. Abbasi, et al. [16] reported that tilling soil reduces soil organic carbon, soil bulk density, and soil aggregates compared to the no-till method. Results of research conducted by Bahrpour, et al. [17] revealed that conservation tillage methods increased soil organic matter and moisture content, and decreased soil bulk density and penetration resistance compared to the conventional tillage because of retaining crop residue on the soil. Results of research conducted by Sessiz, et al. [18] indicated that conventional tillage method in corn produced more yield than reduced tillage; however, there was no significant difference among the treatments in seedling emergence. Results of a research showed that tillage and planting methods had significant effect on wheat yield in cotton residue so that using moldboard plow and broadcasting the seed produced the lowest grain yield [19]. Results of a study on crop residue management and tillage methods on soil properties in wheat-cotton cropping system demonstrated that treatments had no significant influence on soil organic matter and pH [20]. The main aim of this study was to determine the effects of residual management methods on the soil properties and crop yield in corn-wheat cropping system during four years research, and to introduce a proper residue management method for corn-wheat rotation in Fars province, Iran.

2. MATERIALS AND METHODS

A four years field experiment was carried out with planting corn (SC 704 hybrid) and wheat (Chamran cultivar) in Darab Research Station of Fars province (250 KM south-east of Shiraz, Latitude 28º47′ N, 57º17′ E, and 1120 m above sea level with semi-arid climate condition), Iran from September 2005 to September 2009. This research was conducted in the form of a split plot experiment with the base of randomized complete block design (RCBD) with three replications. Main-plots were wheat residue management methods including 1) shredding the residue using shredder and tilling with moldboard plow (25 cm) and disk harrow; 2) shredding the residue using shredder and tilling with chisel plow and rotivator; 3) retaining the crop residue on the soil surface without any tillage operation (no-till); and 4) burning the residue and tilling with moldboard plow (25 cm) and disk harrow. Corn residue management methods including 1) Stalk shredding using stalk shredder, burying the chopped stalk using moldboard plow (25 cm), and applying disk harrow; 2) burning residue (conventional method) were considered as sub-plots. Parameters consisting of bulk density, soil cone index, soil organic carbon, percentage of seed emergence, and crop yield were measured. All residues of corn and wheat were kept on the field experiment and then the treatments were applied (the amount of residue for corn and wheat were 11200 and 8100 kg ha^{-1}, respectively).

Wheat (Chamran cultivar) was planted with row space of 15 cm and corn (SC 704 hybrid) with the row spacing of 75 cm and seed spacing of 20 cm. The seed rate for wheat and corn were 180 kg ha^{-1} and 25 kg ha^{-1} , respectively. Irrigation was carried out every 14 days for wheat and every 8 days for corn. Weeds were controled by applying Atrazine (1.5 kg ha^{-1}) and lasso (4.5 lit ha^{-1}) in corn and Granstar (20 g ha^{-1}) in wheat. The plot size was 80 m^2 (20 m×4 m). Collected data were analyzed using SAS statistical software and Duncan's multiple range tests was used to compare the treatments means. Soil specifications of the field in which experiments were performed are presented in Table 1.

The implements used for preparing treatments were moldboard plow, chisel plow, tandem disk harrow, and stalk shredder. Bulk density in each plot was measured using the core sampler method. Intact soil core samples with a 5.4 cm diameter and 4 cm height were taken using a core sampler [21]. The samples were dried

Table 1. Soil specifications of the field used for study

Soil depth (cm)	Sand (%)	Clay (%)	Silt (%)	O.C (%)	pH	EC (dS m^{-1})	Soil texture
0-15	36.5	19.1	42.8	0.74	7.9	0.51	Loam
0-30	37.9	19.3	41.4	0.73	8.1	0.54	Loam

at 105 degrees centigrade for 24 hours in oven. The following equation was used to calculate the soil bulk density:

$$BD = \frac{W_d}{V} \quad (1)$$

where:

BD = soil bulk density (Mg m^{-3}),
W_d = sample dry weight (Mg), and
V = Sample total volume (m^3).

Cone penetration resistance (PR) was measured using a digital cone penetrometer (Model Rimik CP20, Agridry Rimik Ltd, Queensland, Australia). Penetration resistance was measured for the soil depth of up to 30 cm with the distance interval of one centimeter before and after tillage operation. Organic carbon was measured two times during the study (before applying the treatments in 2005 and at the end of experiment in 2009) using Nelson and Sommers [22] method and variation of organic carbon was calculated based on difference between two measurements in percent.

The number of plants at full emergence was determined by counting the number of seedlings in two rows with the length of 1 m in each plot. Percentage of seeds emerged was calculated by the following equation for wheat and corn:

$$SE = \frac{PPSM}{(SPSM)(P)(G)} \times 100 \quad (2)$$

Where SE is seed emergence (%), $PPSM$ is the number of emerged seed in 1 m^2 of each plot, $SPSM$ is the number of planted seeds in 1 m^2 of each plot, P is seed purity, and G is viability of seeds. Yield for wheat and corn was separately measured using combine harvester. Data collected from this study were analyzed using SAS software, [23], and Duncan's multiple range tests was used to compare the treatments means.

3. RESULTS AND DISCUSSION

Variance analysis of data collected for different parameters showed that corn residue management methods had significant effect on soil bulk density, soil organic carbon, corn seed emergence, corn yield and wheat yield, while wheat seed emergence was not affected by corn residue management methods (Table 2). Results also indicated that wheat residue management methods had significant effect on soil bulk density, soil organic carbon, wheat seed emergence, corn seed emergence, corn yield and wheat yield (Table 2). Soil bulk density, soil organic carbon, corn seed emergence, and corn yield were significantly affected by interaction between corn and wheat residue management methods; whereas, interaction between corn and wheat residue management methods had no significant effect on wheat seed emergence and wheat yield.

3.1 Organic Carbon

Soil organic carbon increment in different treatments during research period is presented in Table 3. Treatment A_1B_2 (Shredding the corn and wheat residue, tilling with moldboard plow and disk harrow for wheat planting, and tilling with chisel plow and rotivator for corn planting) had the highest amount of organic carbon increment due to uniformly mixing the residue with soil in comparison with other treatments. Solhjou et al. [24] reported that chopping rice and corn residue using stalk shredder was more efficient than using disk harrow and rotivator alone. Considering results presented in Table 3, there was a significant difference between treatments A_1B_2 (16.61% of organic carbon increment) and A_2B_4 (7.37% of organic carbon increment) from the organic carbon increment point of view. This showed that adding shredded corn and wheat residue could considerably increase the soil organic carbon. On the other hand, treatment in which corn and wheat residue had been burned had the lowest organic carbon increment in the soil. In A_2B_2 treatment, the percentage of soil organic carbon increase was high, because of chopping the residue of the wheat by the shredder and mixing with soil by the rotivator. The low organic carbon increment in treatments A_2B_3 and A_2B_4 showed that burning residue was the worst treatment from the organic carbon enhancement point of view.

3.2 Bulk Density and Penetration Resistance

Interaction effects of different treatments on the soil bulk density and cone index are presented in Table 4. According to the results shown in Table 4, again treatment A_1B_2 showed the highest

Table 2. Variance analysis of collected data

Variation sources	Degree of freedom	Reduction in soil bulk density (%)	Organic carbon (%)	Wheat seed emergence (%)	Corn seed emergence (%)	Corn yield (kg ha^{-1})	Wheat yield (kg ha^{-1})
Year	3	* 0.46	** 821.3	ns 70.35	ns 3.56	ns 116562	ns 146025
Corn residue (A)	1	** 57.37	** 179.5	ns 227.89	** 192.27	** 3512420	** 2831127
Wheat residue (B)	3	** 76.92	** 241.3	** 1189.16	** 342.06	** 5688163	** 5654667
B × A	3	** 4.71	** 6.82	ns 102.17	** 100.69	** 487965	ns 128214
Year × Factor A × Factor B	9	ns 0.29	** 0.01	ns 59.55	ns 1.69	ns 56848	22736 ns
Error	48	ns 0.22	0.00	55.74	9.59	87316	97126

Table 3. Soil organic carbon increment in different treatments

Treatments	Organic carbon Increment (%)
A_1B_1	15.07 b
A_1B_2	16.61 a
A_1B_3	11.53 d
A_1B_4	8.76 e
A_2B_1	11.03 d
A_2B_2	13.88 c
A_2B_3	8.72 e
A_2B_4	7.37 f

Averages with different letters were statistically different at the confidence level of 95%.
A_1= Shredding the corn residue by stalk shredder, burying the residue by mold board plow and disk harrow.
A_2= Burning corn residue, tilling by moldboard plow and disk harrow.
B_1= Shredding the wheat residue, tilling by moldboard plow (depth of 25 cm) and disk harrow.
B_2= Shredding the wheat residue, tilling by chisel plow and mixing the residue with soil using rotivator.
B_3=Leaving the wheat residue on the soil surface without tilling.
B_4= Burning wheat residue, tilling the soil by moldboard plow and disk harrow.

reduction in the soil bulk density (6.22%) and cone index (12.63%), while the lowest reduction in the soil bulk density (1.27%) and cone index (5.12%) was obtained from treatment A_2B_4 (burning corn and wheat residue). Therefore, one could conclude that adding shredded corn and wheat residue to the soil could significantly decrease the soil compaction by improving soil structure. Comparing treatments A_1B_1 and A_1B_2 from the stand point of soil organic carbon increment and bulk density and cone index reduction revealed that tilling by chisel plow and mixing the residue with soil using rotivator had better performance compared to tilling by moldboard plow and disk harrow. Also, comparing treatments A_1B_1 and A_1B_2 showed that the method of mixing residues with soil and the use of secondary tillage implement created a difference between the two treatments. Chisel plow did not completely inverse the residues, but the use of a rotivator instead of disk harrow is important in mixing residues and uniformly incorporating with the soil. Incorporating the residues into the soil increases soil organic matter and improves the soil aggregates which all contribute to reducing the soil bulk density [25]. The trend of soil cone index variation was same as the soil bulk density changes. Soil porosity increment (soil bulk density reduction) by using rotivator has been also reported by Alvarenga et al. [26].

Table 4. Soil bulk density and cone index reduction in different treatments

Treatments	BD reduction (%)	Cone index reduction (%)
A_1B_1	5.62 b	11.79 b
A_1B_2	6.22 a	12.63 a
A_1B_3	4.31 d	11.27 c
A_1B_4	1.73 f	7.15 e
A_2B_1	3.50 e	10.24 d
A_2B_2	5.02 c	11.19 c
A_2B_3	1.91 f	7.22 e
A_2B_4	1.27 g	5.12 f

Averages with different letters were statistically different at the confidence level of 95%.
A_1= Shredding the corn residue by stalk shredder, burying the residue by mold board plow and disk harrow.
A_2= Burning corn residue, tilling by moldboard plow and disk harrow.
B_1= Shredding the wheat residue, tilling by moldboard plow (depth of 25 cm) and disk harrow.
B_2= Shredding the wheat residue, tilling by chisel plow and mixing the residue with soil using rotivator.
B_3=Leaving the wheat residue on the soil surface without tilling.
B_4= Burning wheat residue, tilling the soil by moldboard plow and disk harrow.

3.3 Yield

Means comparison of treatments from the seed emergence and crop yield point of view (Table 5 and 6) indicated that the maximum seed emergence and crop yield in both wheat and corn was obtained from the treatment containing shredding the corn and wheat residue, tilling with moldboard plow and disk harrow for wheat planting, and tilling with chisel plow and rotivator for corn planting (A_1B_2). This treatment had the highest reduction in the soil bulk density and soil cone index, and the largest enhancement in the soil organic carbon; therefore, seed emergence and crop yield improvement in this treatment was because of improving soil physical conditions. Burning corn and wheat residues provided the worst physical condition for the soil; therefore, the lowest crop yield in both corn and wheat was related to the treatment A_2B_4. Reduction seed emergence, seed emergence rate, and crop yield in corn residue treatments were probably related to increasing soil pH in these treatments. According to results of a research, burning wheat residue increases soil pH, while burying the residue has no significant effect on soil pH rate

Table 5. Effect of experimental treatments on the wheat emerged seed, seed emergence rate and yield

Treatments	Seed emergence (%)	Seed emergence rate (%)	Yield (kg ha^{-1})
A_1B_1	91.32 a	5.28 b	5688.18 b
A_1B_2	93.37 a	5.76 a	5953.70 a
A_1B_3	87.72 a	4.53 c	5696.46 b
A_1B_4	75.95 b	3.94 d	4858.58 c
A_2B_1	88.05 a	4.46 c	5764.13 b
A_2B_2	91.52 a	5.32 b	5798.48 b
A_2B_3	79.18 b	3.42 e	4849.38 c
A_2B_4	77.30 b	3.39 e	4563.74 d

Averages with different letters were statistically different at the confidence level of 95%.
A_1= Shredding the corn residue by stalk shredder, burying the residue by mold board plow and disk harrow.
A_2= Burning corn residue, tilling by moldboard plow and disk harrow.
B_1= Shredding the wheat residue, tilling by moldboard plow (depth of 25 cm) and disk harrow.
B_2= Shredding the wheat residue, tilling by chisel plow and mixing the residue with soil using rotivator.
B_3=Leaving the wheat residue on the soil surface without tilling.
B_4= Burning wheat residue, tilling the soil by moldboard plow and disk harrow.

Table 6. Effect of experimental treatments on the corn emerged seed, seed emergence rate and yield

Treatments	Seed emergence (%)	Seed emergence rate (%)	Yield (kg ha^{-1})
A_1B_1	92.70 a	5.38 b	9318.18 a
A_1B_2	93.50 a	5.85 a	9399.24 a
A_1B_3	85.24 c	4.54 d	8650.13 b
A_1B_4	83.00 c	3.90 e	8258.41 c
A_2B_1	84.78 c	4.50 d	8606.39 b
A_2B_2	90.12 b	4.88 c	9135.15 a
A_2B_3	83.19 c	3.80 ef	8289.14 c
A_2B_4	85.01 c	3.52 f	8065.26 c

Averages with different letters were statistically different at the confidence level of 95%.
A_1= Shredding the corn residue by stalk shredder, burying the residue by mold board plow and disk harrow.
A_2= Burning corn residue, tilling by moldboard plow and disk harrow.
B_1= Shredding the wheat residue, tilling by moldboard plow (depth of 25 cm) and disk harrow.
B_2= Shredding the wheat residue, tilling by chisel plow and mixing the residue with soil using rotivator.
B_3=Leaving the wheat residue on the soil surface without tilling.
B_4= Burning wheat residue, tilling the soil by moldboard plow and disk harrow

[25]. Significant increase in soil pH is due to the burning of plant residue which enhance the chemical elements such as K and Ca that play an important role in reducing soil acidity and increasing soil pH. Wheat produces the highest yield in soil neutral or near neutral pH. In treatments that residue have been burned, the soil pH balance reduced over a period of four years. Alberta [27] reported that adding residue into the soil, prevented soil pH fluctuations. In regard to seed parameters, the seed emergence rate should also be considered along with the percentage of seed emergence. Quick and complete seed germination and emergence improve the likelihood of achieving more and better performance [28]. High rate of seed emergence, especially in hot regions, is likely to be related to the positive role of wheat residue in reducing evaporation from the soil surface and maintaining soil moisture content [29].

4. CONCLUSION

The following conclusions could be drawn from the results of this study:

1. Adding shredded crop (corn and wheat) residue to the soil increased the soil organic carbon.
2. Soil bulk density and cone index (soil compaction) decreased by incorporation of the chopped crop residue to the soil.
3. Adding chopped corn and wheat residue to the soil improved corn and wheat seed emergence and yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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