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Wheat yield and soil properties as influenced by crops residues and nitrogen rates

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Abstract

Incorporation of crop residues into the soil as a source of nutrients and conservation has been widely accepted worldwide. Considering the proper previous crop residues management in wheat (*Triticum aestivum* L.) production, a biennial (2010-2012) experiment was conducted to determine the influence of nitrogen (N) and some crops residues on wheat grain yield and some soil properties at College of Agriculture, Shiraz University, Iran. The experiment was carried out as split-split plot arranged in randomized complete blocks design with four replications. Treatments were N rates (45, 90, 135 and 180 kg ha^{-1}) as main plots, type of crops residues [no residues (control), corn (*Zea mays* L.), rapeseed (*Brassica napus* L.), sunflower (*Helianthus annuus* L.) and wheat] as sub plots and rates of crops residues (25 and 50%) as sub-sub plots. The highest yield was obtained from no residue treatment in the first year and sunflower residues incorporation in the second year. The highest soil organic matter (SOM) contents were obtained from 135 kg ha^{-1} N in the first year, and 90 kg ha^{-1} N with 50% of sunflower residues incorporation in the second year. The highest soil Ncontents (SNC) were achieved with 135 kg ha^{-1} N and 25% of sunflower residues in the first year, 90 kg ha^{-1} N and 50% of sunflower residues, and 180 kg ha^{-1} N and 50% of corn residues incorporation in the second year. Incorporation of all crop residues reduced wheat yield, but incorporation of 25% sunflower residues had the lowest yield reductions and the highest SOC and SNC.

Keywords: crop residues;grain yield;LAI;nitrogen;organic matter.
Abbreviations: HI_ harvest index; LAI_ leaf area index; SOM_ soil organic matter; SNC_ soil N contents.

Introduction

Population growth intensifies food problems in developing countries, which requires improvement in quantity and quality of agricultural products as well as fertilizer use. Unbalanced use of chemical fertilizers reduces soil fertility and quality of crops (Malakooti and Gheybi, 2003). In particular, N forms are very mobile and soluble, they will be lost quickly through leaching, volatilization, and nitrification. Therefore, optimizing the use of chemical fertilizers is an important factor in increasing agricultural productions. To decrease the application of fertilizers, soil incorporation of crop residues has been suggested as a method of improving soil physical, chemical, and biological properties as well as conserving water and reducing excessive evaporation (Stott et al. 1990; Fischer et al. 2002; Ercoli et al., 2008). Crop residues as a natural resource are generally parts of crops retained in soil after harvesting (Kumar and Goh, 2000; Blanco-Canqui and Lai, 2009). Incorporation of crop residues into the soil as a source of nutrients and conservation has been increasing in many parts of the world.Crop residues incorporation releases nutrients into the soil and builds up soil organic matter) after decomposition. However, in some situations, crop yield reduces for various reasons such as lack of proper tillage implements and insufficient farmer's knowledge about the crop residues management, retaining heavy residues in wet soil, problems of pests and diseases incidence, weed control, and reduced availability of nutrients for the next crop (Torbetet al., 1999). Crop sequence influence seed yield as well. Seeding crops into their own residues generally result in low seed yields (Tanaka et al., 2007; Hejazi et al., 2010). Tanaka et al. (2007) showed that the highest seed yield for eight of the 10 crops resulted in synergistic effects when the previous crop was chickpea (*Cicer arietinum*L.) or lentil (*Lens culinaris* Medik.), in the first year and chickpea in the second year compared to each crop grown on its own residues. Heavy residues of irrigated crops left on the soil surface can reduce grain yield due to poor crop establishment, disease transmission or N immobilization (Rieger et al., 2008). In some parts of Iran, farmers sow consecutive irrigated crops with heavy residues and still burn residues for quick seedbed preparation, which leads in SOM loss and fertility reduction. There is no enough information available on residues management to sow crops practically into previous crop residues. The purpose of this experiment was to evaluate the effects ofcrop residues types and N rates in rotation with wheat with improved grain yield and soil properties in long term.

Results and Discussion

Effects of treatments on wheat grain yield, harvest index (HI), leaf area index (LAI) and leaf chlorophyll contents (LCC)

Grain yield

Wheat grain yield was significantly influenced by crops residues types and rates, N rates and the year. Incorporation of different crops residues significantly influenced grain yield with the highest yields were obtained from no crop residues and sunflower residues in the first and the second years,

Table 1. Mean air temperature and rainfall values during the crops growing season, 2010-2011 and 2011-2012*.

	Rainfall (mm)			Temperature (°C)		
	2010-2011	2011-2012	30-years mean	2010-2011	2011-2012	30-years mean
October	0	23.5	21.2	10.7	11.2	10.3
November	0	79.5	80	5.6	4.6	5.8
December	48.5	61	91.7	3.3	4.5	3.3
January	107.5	127	83	4.7	4	3.7
February	71.8	27	63	8.6	5.8	7.2
March	30.5	45	44.5	11.8	11.1	11.1
April	0	0	12.6	17.7	17.2	16.0
May	0	0	0.8	24	21.5	20.4
June	0	0	0.3	27.2	24.3	23.9

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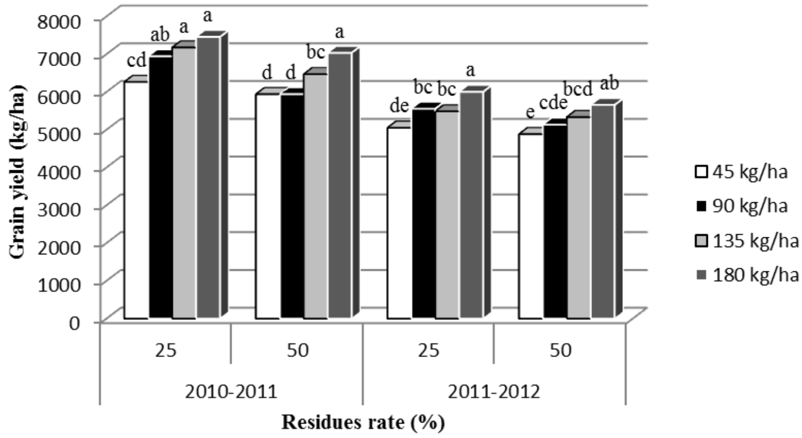

Fig 1. Interaction between N and residues rates on wheat grain yield. Columns with similar letters are not significantly different (DMRT, p≤%5).

Table 2. Some soil properties of experimental site.

Organic matter (%)	1.432
N (mg kg^{-1})	0.127
K (mg kg^{-1})	300
P (ppm)	22.300
pH	7.840
EC (dS m^{-1})	0.927

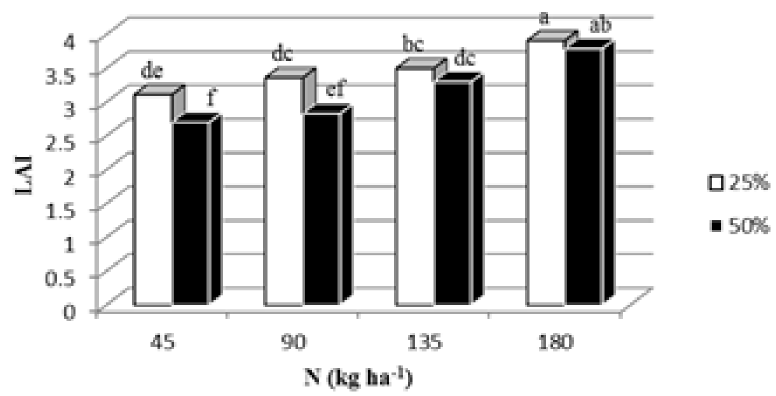

Fig 2. Interaction between N and residues rates on wheat LAI. Columns with similar letters are not significantly different (DMRT, p≤%5).

respectively(Table 4), which is similar to Rieger et al. (2008) for no residue treatment. Increasing residues rates from 25 to 50% significantly decreased grain yield (Table 4). Rahimizadeh et al. (2013) reported that the highest grain yield was obtained from double cropping of potato, *(Solanum tubersum L.)* with wheat compared with other crops and crop residues incorporation had no significant effect on grain yield. Increased N rates significantly increased wheat grain yield in both years (Table 4) which is similar to the findings of Hejazi et al. (2010) and Alijani et al. (2012). Interaction between N and residues rates showed that the highest and the lowest grain yield were achieved with 180 kg ha^{-1} N and 25% of crop residues, and 90 kg ha^{-1} N and 50% of crop residues in the first year, and with 180 kg ha^{-1} N and 25% of crop residues, and 180 kg ha^{-1} N and 50% of crop residues incorporation in the second year, respectively (Fig. 1).Grain yield was significantly lower in the second year than the first year due to crop residues accumulation. Rainfall occurs mainly during fall and winter seasons in the region, which is unsuitable for crop residues decomposition (Table 1). Therefore, undecomposed residues remained in the field in the second year, and it appeared that nutrient contents of residues have not been converted into a readily available form during the experimental period. All of these could immobilize a relevant amount of soil mineral N and reducing its availability to wheat crops as well as increased competition between crops and soil microbes to obtain N. Furthermore, the colder weather conditions of the second year reduced seedling establishment and plant population (Table 1). However, the reduction in grain yield was positively correlated with mean grain weight loss.

HI

Year, crops residues types and rates, and N rates had significant effects on HI. HI was significantly influenced by the incorporation of crops residues and the highest HI was obtained when wheat was sown into no residues in the first year and in sunflower residues plots in the second year. The lowest HI was achieved by rapeseed residues in both years.The highest HI was obtained from 180 kg ha^{-1} N with no significant difference with 135 and 90 kg ha^{-1} N in the first year (Table 4).This can be due to the effect of N rates on grain and biological yields. Lopez-Bellido et al. (2000) showed that increasing N rates (0, 50, 100, and 150 kg ha^{-1}) had no significant effect on HI. Sadeghi et al. (2009) showed that barley (*Hordeum vulgare* L.) HI was influenced by N and crop residues rates and elevated by increased N and crop residues rates. HI decreased in the second year compared to the first year. It seems that more dry matter had accumulated in plant vegetative tissues and this can be attributed to allocating lower portion of assimilates to the seeds.

LAI

Year had no significant effects and crop residues types and rates and N rates had significant effects on LAI.Type of crop residues had different effect on LAI and the highest LAI was obtained when wheat was sown into the sunflower residues. While, LAI decreased with rapeseed residues (Table 4); increased rate of crop residues incorporation from 25 to 50%, significantly decreased LAI (Table 4). Increased N rates significantly increased LAI (Table 4) which is similar to Potter et al. (1995) and Sinclair and Horie (1989) results who found that LAI and crop growth were affected by N rates. Interaction between N and crops residues rates indicated that the highest and the lowest LAI were obtained from 180 kg ha^{-1} N and 25% of crop residues, and 45 kg ha^{-1} N and 50% of crop residues, respectively (Fig. 2). Nitrogen deficiency delays growth and phenological development of the plant, has a negative impact on the light use efficiency, reduces LA expansion, and LAI (Uhart and Andrade, 1995). It seems that higher N rates and 25% of residues incorporation provided favorable conditions for decaying crops residues and adding up nutrients and organic matter into the soil, which provided good substrate for seedling growth and increased biomass via increasing leaf area.

Table 3. Percentage of N and C: N ratio of crops.

Residues type	%N	C:N
Corn	0.24	106.87
Rapeseed	0.36	81.8
Sunflower	0.38	88.5
Wheat	0.3	125.4

Effects of treatments on some soil properties

SOM

Types and rates of crop residues, N rates and year had significant effects on SOM. Incorporation of different crops residues into the soil had different effects on SOM with the highest SOM was obtained when sunflower residues was incorporated into the soil in both years (Table 4). SOM significantly increased in the second year, which may be due to increased rate of accumulated residues with high carbon contents, residues decomposition and nutrient immobilization. Higher N rates increased SOM in both years (Table 4). Interaction between N rates, residues types and rates showed that the highest SOM content was obtained from 135 kg ha^{-1} N and 50% of sunflower residues incorporation in the first year, and from 90 kg ha^{-1} N and 50% of sunflower residues incorporation in the second year (Table 5). Allmaras et al. (2004) showed that N fertilizer increased stover carbon by 20% compared with no N with corn residues incorporation. Clapp et al. (2000) and Alijani et al. (2012) showed that incorporation of corn residues into the soil with N application increased SOM in 30 cm of soil depth. Bahrani et al. (2012) reported that wheat residues incorporation significantly increased SOM. Crop residues removal reduced soil organic carbon, particularly when coupled with moldboard plow treatment (Chivenge et al., 2007). Mann et al. (2002) and Alijani et al. (2012) reported that crop residue removal from agricultural lands, particularly associated with conventional tillage accelerated SOC decline.

SNC

Similar to SOM, year, crop residues types and rates and N rates had significant effects on SNC. Incorporation of different crops residues had significant effects on soil N with the highest and the lowest SNC from incorporation of sunflower residues into the soil in both years and from corn residues in the first year, respectively (Table 4). Increased N rates significantly increased SNC in both years (Table 4). SNC were significantly higher in the second than the first year, which may be due to the increased residues decomposition with N application, increasing immobilized N and reducing inorganic N uptake by plants. Interaction between N rates, residues types and rates showed that the highest SNC were achieved with 135 kg ha^{-1} N and 25% of sunflower residues incorporation in the first year, and with 90 kg ha^{-1} N and 50% of sunflower residues, and 180 kg ha^{-1} N and 50% of corn residues incorporation in the second year (Table 6). Jagadamma et al. (2008) showed that increasing N

Table 4. Effect of N rates, crop residues types and rates on wheat growth and yield, and soil properties.

	Grain yield (kg ha^{-1})		HI (%)		LAI	SOM (%)		SNC (%)	
N (kg ha^{-1})	2010-2011	2011-2012	2010-2011	2011-2012	Mean 2010-2012	2010-2011	2011-2012	2010-2011	2011-2012
45	6102.4d	4422.9d	43.24b	38.47b	2.91d	1.44b	2.64a	0.071c	0.124b
90	6440.2c	5099.4c	44.86a	40.19ab	3.15c	1.43b	2.64a	0.071c	0.128ab
135	6823.3b	5557.8b	44.87a	40.85ab	3.41b	1.49ab	2.65a	0.074b	0.130ab
180	7246.3a	6209.2a	45.11a	42.87a	3.85a	1.54a	2.66a	0.078a	0.135b
Residues type									
control	7905.1a	4904.8c	45.28a	39.59b	3.53b	1.54a	2.46c	0.077a	0.122c
Corn	6296.2c	5648.5b	42.04cd	41.33ab	3.35c	1.43b	2.63b	0.070b	0.128b
Rapeseed	6164.3c	4964.9c	41.18d	39.24b	2.72e	1.43b	2.62b	0.071b	0.130b
Sunflower	6912.9b	6213.7a	43.82b	42.89a	3.91a	1.55a	2.90a	0.080a	0.135a
Wheat	5986.7c	4879.7c	42.38c	39.93b	3.12d	1.44b	2.61b	0.071b	0.130b
Residues rate (%)									
25	6960.1a	5506a	43.19a	41.27a	3.50a	1.40b	2.57b	0.075a	0.129a
50	6346b	5138.6b	43.85a	39.92a	3.16b	1.58a	2.72a	0.072b	0.129a

Mean of each column in each treatment followed by similar letters are not significantly different (DMRT,p≤%5)

Table 5. Effects of N rates, crop residues type and rates on SOM (%).

		2010-2011 N (kg ha^{-1})				2011-2012 N (kg ha^{-1})			
Residues type	Residues rate (%)	45	90	135	180	45	90	135	180
Control	25	1.54bcd	1.30efg	1.62bc	1.70ab	2.45gh	2.36hi	2.61ef	2.45gh
	50	1.54bcd	1.30efg	1.62bc	1.70ab	2.45gh	2.36hi	2.61ef	2.45gh
Corn	25	1.22fg	1.30efg	1.38def	1.38def	2.45gh	2.61ef	2.53fg	2.44gh
	50	1.63bc	1.54bcd	1.54bcd	1.46cde	2.69de	3.02b	2.77cd	2.60ef
Rapeseed	25	1.46cde	1.30efg	1.30efg	1.29efg	2.69de	2.61ef	2.36hi	2.61ef
	50	1.54bcd	1.54bcd	1.38def	1.63bc	2.85c	2.77cd	2.44gh	2.69de
Sunflower	25	1.30efg	1.46cde	1.38def	1.47cde	2.69de	2.69de	2.85c	2.77cd
	50	1.54bcd	1.70ab	1.87a	1.70ab	2.85c	3.19a	3.10ab	3.09ab
Wheat	25	1.13g	1.46cde	1.38def	1.46cde	2.54fg	2.52fg	2.52fg	2.77cd
	50	1.54bcd	1.46cde	1.46cde	1.63bc	2.77cd	2.29i	2.69de	2.77cd

Mean of each column in each treatment followed by similar letters are not significantly different (DMRT, p≤%5).

Table 6. Effects of N rates, crop residues type and rate on SNC (%).

		2010-2011 N (kg ha^{-1})				2011-2012 N (kg ha^{-1})			
Residues type	Residues rate (%)	45	90	135	180	45	90	135	180
Control	25	0.064i-l	0.078c-g	0.082bcd	0.086abc	0.110e	0.135abc	0.120cde	0.125b-e
	50	0.064i-l	0.078c-g	0.082bcd	0.086abc	0.110e	0.135abc	0.120cde	0.125b-e
Corn	25	0.076c-h	0.056lm	0.078c-g	0.071e-k	0.140ab	0.115de	0.130a-d	0.130a-d
	50	0.062kl	0.080cde	0.067g-k	0.068f-k	0.125b-e	0.135abc	0.110e	0.145a
Rapeseed	25	0.061kl	0.080cde	0.062kl	0.082bcd	0.125b-e	0.115de	0.135abc	0.140ab
	50	0.078c-g	0.073d-j	0.068f-k	0.061kl	0.120cde	0.130a-d	0.135abc	0.140ab
Sunflower	25	0.086abc	0.063j-l	0.095a	0.090ab	0.120cde	0.120cde	0.140ab	0.140ab
	50	0.074d-i	0.077c-h	0.069f-k	0.086abc	0.140ab	0.145a	0.140ab	0.135abc
Wheat	25	0.071e-k	0.078c-f	0.074d-i	0.071e-k	0.135abc	0.135abc	0.130a-d	0.140ab
	50	0.073d-i	0.051m	0.066h-k	0.080cde	0.115de	0.115de	0.140ab	0.135abc

Mean of each column in each treatment followed by similar letters are not significantly different (DMRT, p≤%5).

rates from 0 to 280 kg ha^{-1} significantly increased remaining N in the soil. Barraco et al. (2007) showed that corn residues had slightly lower decomposition rate than other crops residues due to its high C:N ratio, so it can immobilize soil N and reduces its availability to wheat grown after corn. The unexpected increase in SOM and SNC could either be attributed to the accumulation of crop residues with high carbon contents and retaining wheat residues of the first year, which has probably lowered SOM oxidation, or increased rainfall in the second year, resulting in increased residues decomposition rate. Plant roots can be a source of organic matter as well. The experimental site was under alfalfa cultivation before leaving fallow for 6 years, and there were large amounts of N in the soil. Then, N and crop residues added into the soil, also wheat and alfalfa roots decomposed, and reduced seedling establishment and plant population helped increased SOM and SNC.

Materials and Methods

Experimental conditions and treatments

A biennial (2010-2012) experiment was conducted to determine the influence of N and crops residues types and rates on wheat grain yield and some soil properties at the College of Agriculture, Shiraz University, Shiraz, Iran (52° 35′ E, 29° 40′ N and 1810 m). The experiment was carried out as split-split plot arranged in randomized complete blocks design with four replications. Treatments were N rates (45, 90, 135 and 180 kg ha^{-1}) as main plots, type of crops residues [no residues (control), corn (SC704 hybrid), rapeseed (Talayeh cultivar), sunflower (Euroflor cultivar) and wheat (Shiraz cultivar)] as sub plots and crops residues rates 25% (2500, 1000, 750 and 1250 kg ha^{-1}) and 50% (5000, 2000, 1500 and 2500 kg ha^{-1}] for corn, rapeseed, sunflower and wheat, respectively)] as sub-sub plots.The soil group was silty loam fine, mixed mesic, Typic Calcixerpets. Average temperatures and rainfall data on monthly average for two years of study and 30 years means of the region as well as some soil properties are shown in Tables 1 and 2.

Chopped crops residues were imported from off farm and evenly incorporated into the soil with moldboard plow in each plot and plots size were 15 m^2. The average amount of crop residues cover determined by random throwing of four 1m^2 frames after harvesting and these amounts were considered as 100% residue cover for each crop.Then the appropriate rates for 25 and 50% residue cover were calculated and added to the field. The previous crop of the experimental site was irrigated alfalfa (*Medicago sativa* L.).

Wheat (Shiraz cultivar) was planted by pneumatic grain drill (Accord model, Germany) at the rate of 200 kg ha^{-1}. The fertilizers consisted of phosphorus as 100 kg ha^{-1} of triple superphosphate broadcasted at sowing time and N as topdressing during crop growth stages (half at sowing and the other half at the beginning of stem elongation phase). Plots were furrow irrigated every eight days during the non-rainy periods. Weeds were controlled with Total herbicide (30 g ha^{-1}). Crop residues were retained in the field as natural residues after wheat harvesting in the first year as 1.5 t ha^{-1} and the remains were transferred to off-farm.

Growth and yield measurement

At anthesis (147 days after planting), leaf area index (LAI) and flag leaf chlorophyll contents (LCC) were measured by randomly sampling 0.5 m^2 from each plot with Leaf area meter (ΔT device Model) and Chlorophyll meter, respectively. At the end of growth period, grain yield and harvest index (HI) were measured by harvesting 1 m^2 from each plot. Harvested wheat plants were oven-dried at 70°C for 48 h.

Soil properties measurement

Soil samples were taken by auger from 0-30 cm depth at each plot to determine SOM (Nelson and Somners, 1982), N (Bremmer and Mulvaney, 1982), P (Olsen and Dean, 1965) and K (Pratt, 1965). At the start of the experiment, soil samples were taken from areas that had not received N fertilizer and had not been tilled and cropped (Table 2).

Statistical analysis

Data were statistically analyzed by ANOVA using the SAS software,and means were compared by Duncan's Multiple Range test at 5% level of probability.

Conclusions

Incorporation of different crops residues into the soil had different effects on wheat growth and grain yield. The highest grain yield was significantly obtained when wheat was planted into the no residues in the first year and sunflower residues in the second year. Increased rate of all crop residues from 25 to 50% significantly decreased wheat grain yield. Increased N and all crops residues rates increased SOM and SNC with the highest SOM and SNC in sunflower residues in the first year. Incorporation of all crops residues reduced wheat grain yield, however, incorporation of 25% sunflower residues had the lowest yield reduction and the highest SOM and SNC. Nevertheless, further research is needed in longer terms to determine the effects of treatments on soil properties and crop yield. Even though reduction in grain yield is possible in short term, it seems that in long term, optimal yield can be achieved after reaching a balance in SOC decomposition.

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