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Yield and Yield Components of Irrigated Rapeseed-Wheat Rotation as Influenced by Crop Residues and Nitrogen Levels in a Reduced Tillage Method

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Abstract: There are scanty information on rapeseed (*Brassica napus* L.) and wheat (*Triticum aestivum* L.) in many parts of Iran where farmers rotates these crops every other year in the same land. The effects of crop residue types (wheat, rapeseed and no residues), nitrogen (N) levels (0, 75 and 150 kg ha^{-1}) and tillage methods [conventional (mold board plow with one disk) and reduced tillage (chisel plow with one disk)] on yield and yield components of these crops accompanied by soil organic carbon (SOC) variations were investigated at Experimental Research Center, College of Agriculture, Shiraz University, Shiraz, Iran for two years (2007-2009). Rapeseed yield was increased with increasing N levels at all residue types, particularly no residues and at both tillage methods, particularly reduced one and decreased when it was planted in its own residues. The highest wheat yield was obtained when it was planted into the no residues incorporated soil with 150 kg N ha^{-1}. Increase N level resulted in an increased in seed yields of both crops in both years. SOC contents significantly increased with crops residues incorporation into soil and decreased with increasing N level. Crop residues incorporation into the soil not only increase rapeseed seed yield but simultaneously reduce its N requirement, possibly through soil improvement, a step toward sustainable agriculture.

Key words: Crop residues · Reduced tillage · Seed yield · Seeds per pod · Grains per spike · Soil organic carbon content

INTRODUCTION

Soil incorporation of crop residues improves physical, chemical and biological properties of soil, maintains soil productivity by replenishing nutrients, conserves soil water and reduces excessive evaporation. Crop residues can mitigate global climate change by sequestering SOC contents and offsetting CO_2 emissions and other greenhouse gases [1, 2]. However, some studies have shown poor growth of wheat in rapeseed residues or vice versa, including lowered soil temperatures [3] increased diseases incidence [4] and phytoxicity from crop residues [5].

Conservation tillage systems have beneficial effects on soil quality and yields of many crops. It has the potential for increasing water infiltration, use and energy efficiencies, increasing profits and carbon sequestration [6]. Unger and Wise [7] and Anderson [8] observed the positive effect of conservation tillage systems on seed yield of sorghum (*Sorghum bicolor* L.) and proso millet (*Panicum miliaeeum L.*), respectively. However, Edwards *et al.* [9] found that grain yield of maize was less influenced to tillage systems and crop rotation. Lafond [10] found that seed yield increased when rotation cropping system is accompanied with conservation tillage.

N is an important nutrient for crop growth [11]. The significance of higher soil nutrient and particularly N availability in determining the yield quantity and quality of winter rapeseed has been underlined by Colnenne *et al.* [12] and Rathke *et al.* [13].

Rapeseed is a new oilseed crop in Iran and farmers rotates this crop with winter small grains every other year in the same land. However, there is not enough information whether this rotation is sustainable under conventional methods. The purpose of this experiment was to evaluate the effects of crop residue types, tillage methods and N levels on yield and yield components of these crops monitored by SOC contents during the experimental period.

MATERIALS AND METHODS

Field experiments were carried out on a fine mixed, mesic typic Calcixerpets soil at Experimental Research Center, Shiraz University, Shiraz, Iran (52°46 E, 29°50 N

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Table 1: Mean air temperature and rainfall values during the crops growing season at Research Center., College of Agriculture, Shiraz University, Shiraz, Iran

	Rainfall (mm)			Temperature (°C)		
	2007-2008	2008-2009	30-year mean	2007-2008	2008-2009	30-year mean
September	0	0	24.4	10.3	12.3	9.9
October	0	30	77.3	8.1	2.6	8.8
November	0	12	96.2	3.5	0.8	3.4
December	41	12.5	88.2	7.4	4.5	3.5
January	74	35	68.8	7.8	7.4	6.9
February	8.5	27.5	45.6	11.6	11.5	10.9
March	0	52	14.1	16.9	17.1	15.6
April	3.5	18.5	0.9	20.1	22.1	20.1
Total	127	187.5	415.5			

Table 2: Some soil properties of experimental soil

Organic matter (%)	0.780
N (%)	0.089
P (p p m)	22.300
pH	7.830
EC (dS/m)	0.210
Sand (%)	21.280
Silt (%)	60.720
Clay (%)	18.000

and 1810 m) for two cropping years (2007-2009). Data on monthly average temperatures and rainfall for two years of study and 30-years means of the region as well as some properties of soil are shown in Tables 1 and 2.

The experiment was conducted as a split-split plot arranged in randomized complete blocks design with four replications. The treatments consisted of crop residues types [(wheat, rapeseed and no residues (control)] as main plot, tillage methods [conventional (mold board plow with one disk) and reduced tillage (chisel plow with one disk)] as sub plot and N levels (0, 75 and 150 kg ha^{-1}) as sub-sub plot. The land was under irrigated rapeseed cultivation the year before starting the experiment and the average rapeseed residues cover determined by random throwing of 0. 5 m^2 frames after harvesting was 2500 Mg ha^{-1} in both years. Both crop residues were evenly incorporated into soil with disk at 0-30 cm soil depth cm by a light disc prior to planting.

The seeds of rapeseed (Telayeh cultivar) and wheat (Shiraz cultivar) were planted by Pneumatic grain drill (model Accord, Germany) at the rate of 10 and 200 kg ha^{-1}, respectively into the residues incorporated soil in October 8 in both years. N was added to plots for both crops at two times (½ at planting and ½ at stem elongation stage). Plots were uniformly irrigated by siphon at planting time and when no rainfall occur during growing period (Table 1). All plots were kept free of pests and diseases during the experimental period.

Both crops were harvested in June 4 in both years and traits such as seed yield and yield structures (pods per plant, seeds per pod, 1000-seed weight for rapeseed and spikes per plant, grains per spike and 1000-grain weight for wheat) were measured by randomly selecting ten plants in each plot. Rapeseed seed oil contents were determined according to the Association of Official of Analytical Chemists [14]. At each plot, soil samples were taken by auger from 0-30 cm depth and SOC were determined by Kjeldahl [15] method. The experimental data were analyzed using the M STAT C software [16]. Data were statistically analyzed for each year and means were compared by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Effects of Treatments on Rapeseed Yield and Yield Components: Crop residue types and tillage methods had no significant effects on pods per plant and seed yield of rapeseed in both years (Table 3) which is similar to Wilhelm and Wortmann [2] who found crop rotation and tillage methods had no effect on soybean (*Glycine max* L.) yield. It seems that nutrient contents of wheat residues have not been converted into a readily available form during the experimental period and incorporation of crop residues into soil had not any significant advantage to crop planted immediately next season. Other studies showed yield increase of rapeseed with higher N levels [1, 5]. Comparison of N requirement of rapeseed and cereals including wheat also showed that genotypes of rapeseed required higher N level to maintain their seed yield [17, 18].

The highest rapeseed seed yield was obtained when it was planted into the wheat residues incorporated soil with 150 kg N ha^{-1} with no significant difference with no residues treatments in both years and seed yield decreased when it was planted into its own residues (Table 3). The highest pods per plant was obtained when rapeseed was planted into wheat residues incorporated

Table 3: Effects of crop residues types and N levels on yield and yield components of rapeseed

Crop residues type	N (kg ha^{-1})	Seed yield (kg ha^{-1})		Pods per plant		Seeds per pod		1000-seed weight (g)		Seed oil content (%)	
		2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009
Rapeseed	0	1240ab	1140b	123.3b	109.4b	19.35d	19.03e	4.57bc	4.76bc	32.3b	33.36abc
	75	1210ab	1200ab	174.1b	111.0b	24.78ab	22.93b	4.37bc	4.83ab	36.1a	39.84a
	150	1329a	1340a	188.1b	131.4b	24.86ab	21.42bcd	5.9ab	4.82ab	33.8b	33.96b
Wheat	0	1197b	1030b	129.5b	105.3b	20.53cd	21.28cd	4.25bc	4.7c	23.5c	23.52c
	75	1250ab	1250ab	184.0ab	127.2b	25.06ab	20.08be	4.82abc	4.84ab	34.3a	29.28bc
	150	1365a	1361a	203.3a	132.0b	24.04ab	21.76bc	7.55a	4.98ab	30.9ab	34.56ab
No residues	0	1190ab	1190ab	127.5b	127.5b	22.2c	22.20bc	5.2c	4.7c	30.5a	34.38ab
	75	1263ab	1263ab	125.0b	125.0b	24.6ab	24.60a	5.53c	4.83b	35.45a	37.56a
	150	1306a	1306a	184.2ab	184.2a	25.76a	25.76a	6.76c	4.93a	31.00ab	33.18abc

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%)

Table 4: Effects of tillage methods and N levels on yield and yield structures of rapeseed

Tillage methods	N (kg ha-1)	Seed yield (kg ha-1)		Seed oil content (%)		Pods per plant		Seeds per pod		1000-seed weight (g)	
		2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009
Conventional	0	1196ab	1180b	24.8b	26.8b	118.6c	118.6bc	22.7b	22.7b	3.7b	4.63c
	75	1266ab	1280a	25.8b	27.1b	140.6bc	140.6b	24.6ab	24.6a	3.4ab	4.8ab
	150	1301ab	1212a	30.0ab	32.1ab	186.6ab	186.6a	25.6a	25.6a	3.6b	4.91a
Reduced	0	1141b	1116b	28.8b	28.3b	121.2c	103.5bc	17.6c	19.9c	4.6b	4.7b
	75	1199ab	1225a	36.00a	38.3a	188.6a	105.9c	24.0ab	19.6c	4. 7b	4.84ab
	150	1417a	1225a	32.9ab	32.1ab	217.6ab	104.5c	23.2b	20.2c	5.7a	4.84ab

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%)

soil with 150 kg N ha^{-1} in reduced tillage method in first year and in rapeseed residues and conventional tillage with 150 kg N ha^{-1} in conventional tillage in second year (Tables 3 and 5). Lopez-Bellido *et al.* [19] showed no significant effects of tillage methods on pods per plant of faba bean (*Vicia faba* L.). Rapeseed seeds per pod increased by 11.3 and 7.8% in wheat and no residues treatments, respectively. Increase N levels increased seeds per pod by 18.4 and 20.0%, respectively (Table 3). Increase N levels significantly increased seeds per pod in second year. Cheema *et al.* [20] showed a negative correlation between seeds per pod and N levels. The highest seeds per pod were obtained when 150 kg N ha^{-1} was applied in no crop residues treatments in both years. The highest 1000-seed weight of rapeseed was achieved in wheat and no residue incorporated plots with 150 kg N ha^{-1} with no significant difference with other treatments in both years (Table 3).

Increase N levels significantly increased rapeseed seed oil contents up to 75 kg N ha^{-1} with no significant difference with 150 kg N ha^{-1} (Table 3). Wheat and no residues treatments and reduced tillage method increased rapeseed oil contents (Tables 3 and 4). Raji *et al.* [21] showed no significant effect of different tillage methods on seed oil contents of soybean (*Glycine max* L.) The highest seed oil content was obtained in reduced tillage method with 75 kg N ha^{-1}. Steer *et al.* [22] showed that increased N levels decreased seed oil contents of sunflower (*Helianthus annuus* L.).

Effects of Treatments on Wheat Yield and Yield Components: Wheat grain yield significantly increased when it was planted into the no crop residues treatments in both years (Table 5). In another words, rapeseed and wheat residues decreased grain yield of wheat which can be due to better seed germination of wheat in no crop residues plots. Increase N level significantly increased wheat grain yield (Tables 5 and 6). Tillage methods had no significant effect on wheat grain yield which is similar to Halvorson *et al.* [23] results. The highest spikes per plant was obtained in no residue treatment in both years (Table 5) which can be attributed to better tillering. Increase N level increased spikes per plant. Lopez- Bellido *et al* [24] found that N levels increased spikes per plant of wheat with no significant difference between levels.

Table 5: Effects of crop residues types, tillage methods and N levels on wheat grain yield (kg ha^{-1})

	2007-2008	2008-2009
Crop residues type		
Rapeseed	7681c	7450c
Wheat	7812b	7554b
No residues	8230a	8090a
Tillage methods		
Conventional	7790a	7749a
Reduced	7902a	7858a
N (kg ha^{-1})		
0	7561c	7545c
75	7818b	7753b
150	8158b	8112a

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%)

Table 6: Effects of crop residues types and N levels on yield and yield components of wheat

Crop residues type	N (kg ha^{-1})	Grain yield (kg ha^{-1}) 2007-2008	Grain yield (kg ha^{-1}) 2008-2009	Spikes per plant 2007-2008	Spikes per plant 2008-2009	Grains per spike 2007-2008	Grains per spike 2008-2009	1000-grain weight (g) 2007-2008	1000-grain weight (g) 2008-2009
Rapeseed	0	7123c	7108d	3.1c	3.4c	12.48b	11.63d	36.0cd	38.3d
	75	7741b	7111d	3.9b	4.0b	15.25b	13.93c	49.3ab	50.2bc
	150	8181b	8131b	4.9a	4.4b	14.25c	15.06b	49.9ab	54.2b
Wheat	0	7395bc	7205c	3.8c	3.3c	12.12e	13.23c	27.9d	46.0c
	75	7840bc	7327c	3.9b	3.95b	15.58b	15.76b	50.2ab	52.3bc
	150	8203ab	8132b	4.5a	4.9b	15.6b	17.56a	53.6a	52.7bc
No residue	0	7725bc	7725bc	3.3c	3.5c	13.66d	11.6d	42.5bc	52.1bc
	75	8125b	8125b	4.00b	4.0b	15.05b	13.8c	45.0abc	54.5b
	150	8842a	8436a	4.7a	4.28a	17.56a	15.7b	53.7a	61.8a

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%)

Table 7: Effects of tillage methods and N levels on yield and yield components of wheat

Tillage methods	N (kg ha^{-1})	Grain yield (kg ha^{-1}) 2007-2008	Grain yield (kg ha^{-1}) 2008-2009	Spikes per plant 2007-2008	Spikes per plant 2008-2009	Grains per spike 2007-2008	Grains per spike 2008-2009	1000-grain-weight (g) 2007-2008	1000-grain-weight (g) 2008-2009
Conventional	0	7523c	7500bc	2.0c	2.8c	12.48c	11.57c	35.4c	49.3b
	75	7722b	7622b	3.53ab	3.8b	14.25b	14.4b	43.6b	59.9a
	150	8125a	8125a	4.3a	4.00a	15.25a	15.68a	50.0a	61.6a
Reduced	0	7600c	7591bc	2.7c	2.16c	11.12d	12.73c	36.3c	37.8c
	75	7914b	7884b	3.3b	3.25b	14.45b	14.6b	47.5b	36.5c
	150	8192a	8100a	4.7a	4.25a	15.58a	15.86a	57.5a	40.0bc

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%)

The highest grains per spike were achieved in no residue treatment in first year and in wheat residues in second year (Table 6). Increase N levels significantly increased grains per spike in both years. Increase N levels in no residue in first year and in wheat residue incorporated treatment in second year significantly increased grains per spike.

Interaction between crop residues types and N levels indicated that in each crop residue plot, N levels significantly increased 1000-grain weight (Table 6) and the highest 1000-grain weight of wheat was obtained in wheat residues incorporated in first year and in no residues and wheat residue treatments in second year (Table 6). Increase N levels significantly increased 1000-grain weight in both years and the highest 1000-grain weight were achieved in no and wheat residues plots with 150 kg N ha^{-1}. N levels significantly increased grain yield and some yield components at each tillage method (Table 7).

Effect of Treatments on SOC Contents: SOC contents significantly increased when wheat and rapeseed residues were incorporated into soil at the end of second cropping year (Table 8). N levels significantly decreased SOC contents in both years (Table 9). Halvorson *et al.* [23] found that regardless of increased crop residues N application did not bring any significant changes in SOC contents. They also found continued fallow even in no tillage method might lead to soil carbon losses.

Table 8: Effects of crop residues types, tillage methods and N levels on SOC contents (%)

	2007-2008	2008-2009
Crop residues type		
Rapeseed	0.43a	0.47a
Wheat	0.45a	0.51a
No residues	0.40b	0.45b
Tillage methods		
Conventional	0.45a	0.52a
Reduced	0.43a	0.50a
N (kg ha^{-1})		
0	0.47a	0.58a
75	0.45ab	0.53b
150	0.41b	0.51b

Means of each column in each treatment followed by similar letters are not significantly different (Duncan 5%).

Table 9: Effects of crop residue types and N levels on SOC for two years (%)

Crop residues type	N (kg ha^{-1})	2007-2008	2008-2009
Rapeseed	0	0.47ab	0.53b
	75	0.45b	0.5bc
	150	0.40c	0.48c
Wheat	0	0.50a	0.56a
	75	0.47b	0.52b
	150	0.43bc	0.49c
No residues	0	0.46b	0.58b
	75	0.44bc	0.48c
	150	0.40c	0.42d

Means of each column followed by similar letters are not significantly different (Duncan 5%).

In summary, the highest seed yield and yield components of rapeseed and wheat were obtained when both crops were planted into no crop residues incorporated soil with application of 150 kg N ha^{-1}. Crop residues incorporation into the soil and N application increased and decreased SOC contents, respectively and their incorporation not only increase seed yield of rapeseed but simultaneously reduce its N requirement, possibly through improvement of soil properties, a step toward sustainable agriculture. Further researches is required to determine the effects of long term crop rotation on yield and yield components of both crops.

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