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Effects of Preceding Crops and Nitrogen Rates on Grain Yield and Yield Components of Wheat (*Triticum aestivum* L.)

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Abstract: The aim of this study was to evaluate the effects of preceding crops and nitrogen rates on yield and yield components of wheat. The experiment was conducted at the Experimental Farm of Rarmin Agricultural and Natural Resources University, Ahwaz, Iran during 2008-2010 growing seasons. The experimental design was split plot arrangement (RCBD) with three replications. Main plots were different preceding crops wheat, canola, maize, mungbean, rice and berseem clover-barley mixture with control (fallow). Sub plots were nitrogen fertilizer rates (0, 45, 90 and 135 kg N ha^{-1}). Results showed that effects of preceding crops and nitrogen fertilizer rates for grain yield, total dry matter, spike m^{-1}, grains $spike^{-1}$ and 1000 grain weight were significant during both years, while harvest index was significantly different during 2010. There were preceding crop × nitrogen rate interaction for grain $spike^{-1}$ and 1000 grain weight during both years while significant preceding crop × nitrogen rate interaction were determined for grain yield, total dry matter, harvest index and spike m^{-1} in 2010. Results indicated that species of preceding crops significantly affect wheat yield and grain legumes such as mungbean might help to maximize wheat yield in a crop rotation system.

Key words: Nitrogen rate · Preceding crop · Wheat · Yield · Yield components

INTRODUCTION

Wheat is an important staple crop around the world. Its importance has risen even more due to frequently experienced food shortages and its role in world trade. Increasing wheat production to meet higher demands by growing populations is still a challenge in many countries [1]. Winter wheat based rotations are main cropping system in Iran, but little information exists on better preceding crops for wheat under Mediterranean climate in Iran [10]. Until recently most of the research work has been mainly confined to the nutrient requirement of an individual crop and fertilizer recommendation made on the basis of fertilizer response data of a single crop without taking into consideration the effect of preceding crop and soil test value. Now it is increasingly realized that when crops are grown in system, the fertilizer needs of an individual crop cannot be precisely determined without taking into account the nature of preceding crop, it's yield level and residual effect of fertilizer application [8].

Kumar and Sharma [8] reported that growing of a legume crop in the previous season affect the growth and development of wheat. Yields are higher when cereals follow a legume as this saves nitrogen and breaks the disease cycle of grains.

Rapeseed is an important oilseed crop that has an intensive root system, it is also known as a good previous crop for numerous crops. The successful inclusion of oilseed crops in cereal-based cropping systems has been shown to have positive agronomic and economic impacts [11]. Some researchers demonstrated the benefits of crop rotation compared to a monoculture of wheat, they reported increased grain and above ground dry matter yields fallowing canola and field pea than wheat following wheat [2]. Soil nitrogen is a particularly important issue as it plays a key role in achieving quantitatively and qualitatively high yields, although it's easy leaching from the soil can result in the polluting of water tables. Indeed, it has been estimated that on average only 40–60% of mineral nitrogen dressing for wheat is taken up by the

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Table 1: Some soil properties of experimental soil

	Soil depth (cm)	
	0-30	30-60
Organic matter (%)	0.64	0.41
N (%)	0.06	0.03
P (ppm)	8.7	5.9
K (ppm)	2.3	125
pH	7.5	7.9
EC (dS/m)	3.1	2.3
Clay (%)	44	42
Silt (%)	40	39
Sand (%)	16	17

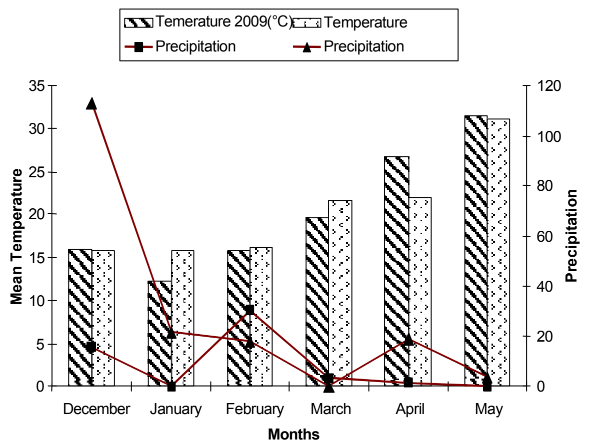

Fig. 1: Meteorological data (temperature: °C and precipitation: mm) for the experimental site during the experimental periods (December-May, 2009 & 2010).

crop and that percentage decreases as the nitrogen input increases, resulting in higher residual soil N-amounts that can readily be leached [5]. The objective of this experiment was to determine the effect of preceding crop and nitrogen fertilizer rate on wheat yield and yield components.

MATERIALS AND METHODS

Field experiments were carried out in a clay loam soil at Ramin Agricultural and Natural Resources University in Ahwaz, Iran (48°53 E, 31°36 N and 50m) in two growing seasons (2008-2010). This site is characterized by Mediterranean climate with hot, dry summers and mild, wet winters. Data on monthly average temperature and rainfall for two years of study as well as some properties of soil are shown in Fig 1 and Table 1, respectively. The experimental design was split plot with three replication. Seven preceding crops (wheat, canola, maize, rice, mungbean, berseem clover-barley mixture and

Table 2: Sowing and harvest time of preceding crops in two growing seasons (2008-2010)

Preceding crop	Sowing date	Harvest date
Berseem clover-barley mixture	10-20 Nov	10-20 May
Canola	20-30 Nov	10-20 May
Maize	20-30 Jul	20-30 Oct
Mungbean	1-10 Jul	1-10 Oct
Rice	20-30 Jun	20-30 Oct
Wheat	20-30 Nov	20-30 May

fallow) were allocated to the main plots. Sub plots were nitrogen fertilizer rates (0, 45, 90 and 135 kg N ha^{-1}) applied to wheat only. Nitrogen fertilizer was applied to wheat plots as urea. At all application rates, ⅓ was applied before sowing, ⅓ at the beginning of wheat tillering and ⅓ at ear emergence. In year first of the trial, each of the seven preceding crops grown separately on seven main plots. The preceding crop residues on plots were shredded by tillage that consisted of disking twice 10-15 cm deep before planting wheat. At the second year, spring wheat (cv. Chamran) was planted fallowing preceding crops on December with arrow spacing of 15 cm and a seeding rate 250 kg ha^{-1}. At harvest a 0.5 m^2 portion at the center of each wheat sub plot was sampled. From this sample total dry matter and grain weight were determined by drying the sampled plants at 60°C for 72h. The harvest index and yield components (grain yield, spike number m^{-2}, spike seed number and 1000 grain weight) were measured. Wheat grain was harvested in late April. Data collected for each parameter were subjected to analysis of variance (ANOVA) using the SAS software (SAS Release 9.2, SAS Institute Inc., Cary, NC, USA). Where the F-ratios were found to be significant, treatment means were separated using the Fisher's Least Significant Difference (LSD) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Grain Yield: In the two study years, grain yield was inversely related to rainfall, with mean value of 4010.36 (2009) and 2967.74 (2010) kg ha^{-1}; differences between years were significant (Tables 3 and 4). As presented in Fig 1, the precipitation during December-May 2010 was higher than the corresponding period in 2009. Thus crop establishment was influenced by water stress (high soil moisture). The effect of the preceding crop on the wheat grain yield was the same in two years of study (Table 4). Wheat grain yield was grater following mungbean than other preceding crops. Siadat *et al*. [12] found that the benefit of the legume crops is related to both nitrogen and the effects of complex rotation procedures. The lowest

Table 3. The mean of squares of grain yield and yield components of wheat at different preceding crop and N rates.

		Mean Square					
Source	df	Grain yield	Total dry matter	Harvest index	Spikes m-1	Grains spike-1	1000 grain weight
Year (Y)	1	45657330.7**	441028809.5**	47.5**	363444.0**	592.6**	42.1**
Blocks/Year	4	47739.1^{ns}	4462390.6^{ns}	24.6**	688.9^{ns}	0.4^{ns}	0.7^{ns}
Preceding crop (P)	6	10337325.7**	99094929.5**	131.7**	73303.1**	91.5**	14.5**
Y × P	6	210582.1**	3481741.9^{ns}	43.1**	3933.7**	18.3**	15.1**
Error a	24	27998.3	2299615.8	5.6	1449.1	2.7	1.8
N Rate (N)	3	34895548.2**	24949522.1**	24.2**	112912.1**	489.5**	28.7**
P × N	18	147778.9**	1560641.1^{ns}	5.5^{ns}	1173.7^{ns}	6.6**	7.8**
Y × N	3	785501.5**	9083571.5**	291.7**	7511.6**	13.2**	0.1^{ns}
Y × P × N	18	341011.6**	3532431.2*	11.6**	1297.7^{ns}	15.2**	5.0**
Error b	84	29947.4	1691474.1	5.4	814.1	1.82	1.5
%CV		14.65	13.22	6.30	7.5	5.23	3.6

* Significant at 0.05 probability level.** Significant at 0.01 probability level.ns non significant.

Table 4: Grain yield and yield components of wheat at different preceding crop and N rates

	Grain yield		Total dry matter		Harvest index	Spikes m^{-1}		Grains $spike^{-1}$		1000 grain weight	
Preceding crop	2009	2010	2009	2010	2010	2009	2010	2009	2010	2009	2010
Fallow	3965.01	2729.15	11114.82	7605.33	33.45	435.65	322.84	28.57	22.31	32.14	36.03
Rice	3108.65	1828.58	8742.26	4228.72	43.64	323.81	234.65	27.74	27.26	34.45	34.95
Maize	3591.28	2532.30	10408.66	7064.26	35.58	409.54	322.11	25.42	22.45	33.86	33.76
Mungbean	4827.93	3989.83	14304.75	11168.96	34.81	489.36	414.18	29.70	25.39	32.73	35.20
Canola	4675.23	3634.63	13157.19	9859.25	37.59	469.25	396.57	28.31	23.61	34.68	35.56
Berseem clover-barley mixture	3868.50	2794.59	10815.12	7881.34	34.90	447.93	306.40	24.46	20.60	33.40	33.14
Wheat	4035.94	3264.97	11624.53	9676.22	33.53	410.75	338.03	29.44	25.54	33.09	32.53
LSD ($p < 0.05$)	169.30	124.17	1846.34	449.86	0.96	45.29	14.98	1.85	0.94	0.78	0.98
N rate (kg ha-1)											
0	2708.23	1718.68	7391.95	5508.99	31.79	363.25	256.19	22.75	19.61	32.24	33.35
45	4171.36	2753.31	11702.84	7783.72	35.73	437.68	314.93	27.68	22.50	34.17	35.12
90	4549.57	3548.39	12849.57	9445.16	37.76	443.83	364.56	30.50	26.37	33.87	34.74
135	4612.28	3850.60	13865.62	10110.13	39.60	461.79	398.48	29.63	27.00	33.62	34.60
Mean	4010.36	2967.74	11452.49	8212.00	36.22	426.64	333.54	27.64	23.87	33.47	34.45
LSD ($p < 0.05$)	132.83	75.02	1117.14	258.09	0.34	24.40	6.06	0.95	0.71	1.74	0.34

yield in both years of the experiment was obtained when wheat was planted after paddy rice (Table 4). In the Ahwaz region, the time between harvesting the rice and seeding the wheat is limited. This means that optimal tillage options cannot be applied, resulting in weak seedling and subsequent lower yields in comparison to other preceding crops. Increase nitrogen fertilizer rates significantly increased grain of wheat in both years (Tables 3 and 4). The highest grain yield of wheat (4612.28 and 3850.60 kg ha^{-1} for 2009 and 2010, respectively) was obtained at 135 kg N ha^{-1}. Positive response of wheat grain yield to nitrogen application has been documented by several authors [1 and 9]. Neverthless, Hejazi *et al*. [6] noted that maximum grain yield of wheat was obtained when 150 kg N ha^{-1} was applied.

Finally, the significant year×preceding crop×nitrogen fertilizer rate interaction (Table 3) indicates that in year which rainfall is distributed uniformly (2009), nitrogen application resulted in yield difference between rotations. These differenced were not observed in the year where yield was lower, due to excessive rainfall (2010). These results agreeing with the findings of Lopez-Bellido *et al*. [9] and Yusuf *et al*. [13] who reported that in years with excessive rainfall, grain yield decreases and nitrogen rate×preceding crop interaction is not significant.

Biological Yield: Results showed that in both years, wheat biomass was affected by preceding crop and nitrogen fertilizer rate while, the interaction between preceding crop and N rate was significant in 2010.

Table 5: Interaction effects of preceding crop and N rates on grain yield and yield components of wheat

		Grain yield	Total dry matter	Harvest index	Spikes m^{-1}	Grains $spike^{-1}$		1000 grain weight	
Preceding crop	N rate	1388	1388	1388	1388	1387	1388	1387	1388
Fallow	0	1347	4233	30	250.31	23.25	16.23	31.08	34.84
	45	2268	7115	31	300.64	28.63	22.69	32.36	37.14
	90	3120	9038	34	345.62	30.05	24.05	32.01	36.51
	135	4180	10034	37	394.52	32.84	27.30	33.54	36.12
Rice	0	1035	2821	37	130.35	23.78	23.18	31.98	32.93
	45	1591	3594	43	210.69	28.56	26.53	34.76	34.08
	90	1944	4145	45	286.01	31.68	31.22	36.71	36.31
	135	2743	6353	47	311.68	29.10	27.69	35.22	35.79
Maize	0	1054	3418	30	255.11	19.62	20.36	35.45	34.80
	45	2270	6309	36	290.67	23.35	22.00	36.18	34.15
	90	3687	10345	35	341.32	28.42	26.31	33.34	32.76
	135	3116	8183	40	401.58	30.75	20.98	30.62	33.19
Mungbean	0	2569	8352	30	328.00	25.26	20.57	32.40	34.47
	45	3661	10045	35	414.81	31.81	22.13	33.09	36.56
	90	4844	12163	39	442.03	32.57	26.41	33.20	35.63
	135	4883	14115	35	472.95	30.21	31.44	33.75	34.26
Canola	0	2418	7835	32	339.65	25.08	19.72	32.28	36.50
	45	3400	9981	36	370.25	29.79	21.08	35.89	35.99
	90	4124	10521	39	441.39	31.04	25.50	36.41	36.00
	135	4595	11098	42	242.54	28.67	28.79	35.33	33.75
Berseem clover-barley mixture	0	1860	6044	31	242.05	18.36	17.43	31.84	31.26
	45	2936	7862	35	289.33	24.80	17.85	34.12	34.85
	90	3160	8952	35	318.41	30.43	22.41	33.62	34.62
	135	3221	8666	37	375.72	25.59	24.05	34.56	33.32
Wheat	0	1744	5857	30	248.23	25.01	21.68	32.30	29.11
	45	3144	9578	32	327.43	29.70	24.59	33.38	33.45
	90	3957	10949	35	377.93	31.63	26.33	33.02	32.48
	135	4213	12319	36	399.30	32.80	30.28	33.00	35.81
LSD ($p < 0.05$)	209.92	734.30	1.21	19.94	2.80	1.86	4.07	1.21	

In years, the highest (14304.75 and 11168.96 kg ha^{-1} for 2009 and 2010, respectively) and the lowest (8742.26 and 4228.72 kg ha^{-1} for 2009 and 2010, respectively) biological yield of wheat was observed for the mungbean –wheat and rice-wheat, respectively. These findings were well supported by many workers like Aslam *et al*. [3]. They reported that the yield of cereal after legume crops was significantly greater than after continuous cereal, but with the application of nitrogen fertilizer further increase the biological yield of cereal after legume crops. Some researchers reported that Mungbean increases the rate of nitrogen and thereby induces vigorous vegetative growth, which in turn results in increase biological yield [1].

Number of Spike/m^2: Number of spike/m^2 was significantly influenced by year, preceding crop and nitrogen rate (Table 3). In 2009, the year with maximum grain yield, the value recorded for number of spike/m^2 was significantly higher than in 2010 (Table 4). The highest number of spike/m^2 was obtained when wheat planted after mungbean in both years (Table 4) which can be attributed to better tillering. Lopez-Bellido *et al*. [9] showed that the increased amount of mineral N present in the soil after legume crops, favored vegetative growth of the wheat and boosted tillering. Increase nitrogen rate increased number of spike/m^2 (Table 4). Lopez-Bellido *et al*. [9] found that nitrogen rates increased the number of spike/m^2 of wheat with no significant difference between tha rates 100 and 150 kg N ha^{-1}.

Number of Grains/Spike: Number of grains/spike was significantly influenced by year, preceding crop and nitrogen rate. The number of grains/spike was the only component where year displayed a significant interaction with all treatments (Table 3). In both years, the highest number of grains/spike was obtained in wheat fallowing wheat with 135 kg N ha^{-1} (Table 5). Hejazi *et al*. [6] showed that the highest number of grains/spike of wheat were achieved in wheat-wheat rotation and increase nitrogen rates significantly increased number of grains/spike which is in accordance with our findings. The lowest number of grains spike was achieved in wheat following berseem clover-barley mixture with 0 kg N ha^{-1}. In our present study conditions and due to the period of the growing season of the region, the length of time which elapsed between harvesting the preceding crop and wheat seeding differed (Table 2); for example, wheat is seeded approximately six months later than berseem clover-barley mixture. Therefore, the effect of this preceding crop is also influenced by the time factor as part of the effects of complex rotation procedures.

1000-Grain Weight: Results showed that wheat 1000-grain wheat was affected by preceding crop and nitrogen fertilizer rates. Moreover, there was a significant interaction between preceding crop and N rate for 1000-grain weight (Table 3). In 2009, the highest 1000-grain weight was recorded for canola-wheat rotation (34.68 g). This rotation produced the highest numbers of ears m^{-2} and highest grain yield, indicating less competition between different growth components of wheat during 2009 which rainfall was uniformly distributed. In 2010, maximum 1000-grain weight was produced in fallow-wheat rotation (36.03 g). This rotation did not produced the highest numbers of ears m^{-2} in contrast to 2009. 1000-grain weight showed strong relation with ears m^{-2}. In addition, the lowest 1000-grain weights of wheat were always associated with the control treatment (no nitrogen) regardless of preceding crops.

Harvest Index (HI): Harvest index of wheat was significantly affected by year, preceding crop and nitrogen fertilizer rate, significant interactions being shown in Table 3. The lowest and highest value for harvest index observed in fallow-wheat (33.45%) rotation and wheat grown after rice (43.64%), respectively (Table 4). In rice-wheat rotation, HI of wheat was significantly higher than other rotations, while there were no significant difference in wheat HI between fallow –wheat and continuous wheat.

Increasing N application rate from 0 to 135 kg N ha^{-1} resulted in increased HI (Table 4). Increasing the rate of nitrogen fertilizer application was shown to increase the HI in other studies [4, 7]. The HI reached it's peak at wheat following rice and 135 kg N ha^{-1} treatment and was lowest at control (continuous wheat and 0 kg N ha^{-1}) (Table 5).

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