Bulgarian Journal of Agricultural Science, 16 (No 6) 2010, 733-739
Agricultural Academy

EFFECTS OF PREVIOUS CROP AND N-FERTILIZATION ON SEED YIELD OF WINTER WHEAT (*TRITICUM AESTIVUM* L.) UNDER RAIN-FED MEDITERRANEAN CONDITIONS

R. DOGAN and U. BILGILI
Uludag University, Department of Field Crops, Faculty of Agriculture, TR-16059 Bursa, Turkey

Abstract

DOGAN, Ramazan and Ugur BILGILI, 2010. Effects of previous crop and N-fertilization on seed yield of winter wheat (*Triticum aestivum* L.) under rain-fed Mediterranean conditions.
Bulg. J. Agric. Sci., 16: 733-739

This research investigated the effects of previous crop covers and nitrogen (N) fertilization level on yield and yield components of wheat (*Triticum aestivum* L.) cultivars during two growing seasons (2001-2002 and 2002-2003) in Turkey under rain-fed Mediterranean conditions. We assessed the effects on seed yield and yield component of: (i) the previous crops, (ii) wheat cultivars, and (iii) nitrogen fertilizer levels. A split-split plot design with three replications was used in this study. Previous crops, alfalfa (*Medicago sativa* L.) and sunflower (*Helianthus annuus* L.), were the main the plots; wheat cultivars (Golia and Pehlivan) were the sub-plots; and five different levels of nitrogen fertilization (0, 50, 100, 150 and 200 kg ha^{-1}) were the sub-sub-plots. Even with different N fertilization levels, the seed yield of wheat after sunflower was less than the yield of wheat after alfalfa both in individual years and averaged across years. Seed yields and all yield components for Pehlivan tended to be greater than those of Golia in individual years and over both years. The optimum N application rate for wheat yields in our study was 150 kg N ha^{-1}. In the dry year of 2002-2003, the reduction in wheat seed yield following all previous crops was accompanied by seed per plant, seed weight per plant and number of plant per square meter.

Key words: previous crop, wheat, grain yield, yield components

Introduction

Wheat is the major crop grown throughout dry area and fallowing has been used traditionally to store water for the following crop (Byram, 1997). Although wheat–fallow cropping systems are widely used in environments where water availability is a major issue, there is renewed interest in cereal rotations with annual or perennial forages rather than monoculture (Pierce and Rice, 1988; Ladha et al., 1996; Tomasoni et al., 2003).

The principal benefit attributed to legumes in crop rotations is their contribution of mineral N to the soil (Badaruddin and Meyer, 1989; Baldock et al., 1981); however, the benefits of forage legumes in cropping systems are likely due to a combination of N contribution and yield-enhancing rotation effects that are not directly associated with N. These non-N rotation

*Corresponding author: rdogan@uludag.edu.tr

effects are attributed to increases in soil organic matter resulting in improved soil structure and increased water infiltration; disruption of pest cycles; and the addition of growth-promoting substances (Liebman, 1988). Wheat yield and protein contents have been increased with N fertilization. However, increases in the rate of N application may result in greater severity of soil water deficits under dryland farming. Winter wheat grown under water stress can have a shorter effective grain-filling period and, consequently, lower kernel weight (Frederick and Camberato, 1995)

Papastylianou (1993) and Lopez-Bellido et al. (1996) found that legumes increased grain yields under rainfed Mediterranean conditions. Sustainable agriculture has revitalized the interest in crop rotations and their effect on N use efficiency for promoting profitable and efficient agriculture. The amount of N fertilizer required under semi-arid climates is largely dictated by seasonal rainfall (Myers, 1984). Long-term experiments have revealed wide variability in the response of wheat to N fertilizer; however, very few of these experiments have included evaluation for more than 3 to 5 years that also accounted for accumulation of and within the soil profile (Westerman et al., 1994). Under semi-arid conditions, periods of intensive accumulation of mineral N can be followed by N depletion, depending on rainfall and crop growth. According to Corbeels et al. (1998), there is a carryover effect of N fertilizer from one growing season to the next in soils under rainfed Mediterranean conditions. Losses of residual N fertilizer between cropping and the following growing season are usually small.

The introduction of high-yielding wheat cultivars has increased the use of N fertilizers in the Mediterranean region. However, increasing N rates does not necessarily improve grain yield and quality. The benefits of legumes in cropping systems are well-established (Giller, 2001; Lopez-Bellido and Lopez-Bellido, 2001; Kumar and Goh, 2002). Legumes have positive effects on the structure and functioning of agroecosystems (Caporali and Onnis, 1992) and reduce the use of N fertilizers (Ofori and Stern, 1987). Many studies have been conducted to examine the effects of N fertilizers and preceding leguminous and nonleguminous crops on cereal grain yield (Rowland et al., 1988; Mason and Rowland, 1990; Lopez-Bellido, 2001; Kumar and Goh, 2002).

The purpose of the present research was to evaluate the possibility of growing winter wheat in an agricultural system that could be characterized by reductions in the use of fertilizer. In this experiment, the particular focus was on the effects of (i) preceding leguminous (alfalfa) and non-leguminous (sunflower) crops and (ii) N fertilizer rates on the yield and seed components of winter wheat genotypes under rainfed Mediterranean conditions.

Materials and Methods

The aim of this research was to determine the effects of previous crops and N fertilization on yield and yield components of wheat (*Triticum aestivum* L.) cultivars during two growing seasons (2001-2002 and 2002-2003) at the Uludag University Research Farm, near Bursa-Turkey (40° 11’ North, 29° 04’ East), 70 m above sea level. The soil was clay loam, slightly alkaline (pH = 7.3), rich in potassium (933 kg K ha^{-1}), medium in phosphorus (70 kg P ha^{-1}) and containing 2.0% organic matter (Table 1).

The local climate is temperate, with hot and dry summers and mild and rainy winters. According to long-term meteorological data (1929-2003), the annual mean precipitation, temperature, and relative humidity are 555.6 mm, 11.4°C, and 71.3%, respectively. The climate of the region is sub-humid, but rainfall is extremely low in the summer period. But, especially precipitation in March, April and May 2001-2002 (264.9 mm) were higher than those of both long-term (182.6 mm) and from second trial year (190.9 mm). Seasonal rainfall was 598.6 mm in 2001-2002, 461.5 mm in 2002-2003 and 555.6 mm in the long-term average (Table 1).

A split-split plot design with three replications was used. The previous crops, alfalfa (*Medicago sativa* L.) and sunflower (*Helianthus annuus* L.), were the main plots, wheat cultivars (Golia and Pehlivan) were the sub-plots and five different levels of nitrogen fer-

Table 1
Monthly temperature (°C), relative humidity (%) and rainfall (mm) in 2001-2002 and 2002-2003 growing periods with long term (1928-2001) averages

	Temperature, °C			Relative humidity, %				Precipitation, mm	
Months	2001-2002	2002-2003	long term	2001-2002	2002-2003	long term	2001-2002	2002-2003	long term
November	10.6	10.7	11.2	69.1	72.6	75.6	104.1	67.9	76.3
December	5.0	5.0	7.6	69.1	67.0	74.2	124.0	28.8	99.9
January	5.6	8.6	5.3	62.7	68.3	74.1	35.0	65.3	88.8
Fabruary	8.3	2.7	6.2	64.7	71.2	73.4	55.5	106.2	77.5
March	12.4	4.4	8.3	62.7	64.0	70.2	87.9	33.1	69.8
April	12.8	9.9	13.0	68.9	70.4	70.3	126.5	112.1	62.9
May	17.5	18.8	17.6	62.9	67.7	69.5	50.5	45.7	50.0
June	23.0	23.8	22.1	54.2	54.8	62.9	15.3	2.4	30.4
Average /Total	11.9	10.5	11.4	64.3	67.0	71.3	598.6	461.5	555.6

tilization (0, 50, 100, 150 and 200 kg ha^{-1}) were the sub-sub-plots. Plot size was 2.4 m × 10.0 m = 24.0 m^2. Each plot consisted of 16 rows and row spacing was 15 cm.

After harvesting the sunflower and alfalfa crops in September, plots were plowed and then harrowed at least 40 days before wheat variety seeding in all experimental years. Alfalfa plots were 5 and 6 years old in the first and second growing period, respectively. Wheat varieties were seeded on 03 November 2004 and 04 November 2005. The seeding rate was 200 kg ha^{-1}. Nitrogen fertilizer was applied to all plots as ammonium nitrate; half was applied at sowing and half as a top dressing at the end of the wheat tillering stage. Weeds were controlled between the tillering and shoot elongation stages with tralkoxydim (22.5%), fluroxypyr (6 g), clopyralid (2.3 g) and MCPA (26.7 g).

The plots were harvested in early to mid July each year by cutting wheat samples for seed yield determination from 2.0 m^2 areas within each plot. Just prior to harvest, ten plants were randomly sampled from each plot to determine plant height, the number of seeds and seed weight per plant characteristics every year. Plant stands were counted at harvest along a 1-m length of the interior rows of each plot in two replications. 1000 seed weight was determined from four replicated 100-seed lots.

Analysis of variance (ANOVA) was performed on the morphological measurements and yield data using the MINITAB (University of Texas at Austin) and MSTAT-C (Version 2.1 Michigan State University, 1991) programs. The significance of main effects was determined by the F test. Differences in treatment means were detected by the LSD test (0.05) for comparison.

Results

An ANOVA indicated that there were statistically significant ($P<0.01$) differences in seed yield and the yield components of the winter wheat cultivars in individual experimental years and the combined two-year results (Table 2). Both the previous crop and N fertilization treatments significantly affected all components of the winter wheat cultivars. There was a close relationship between N fertilization and yield components. In generally, a previous crop of alfalfa gave the highest value in all components.

Plant height was greatly influenced by the previous

Table 2
Effect of previous crop and nitrogen fertilization on the yield and yield components of subsequent winter wheat (average of 2 years)

Factors	Plant height. cm	Seed per plant	Seed weight per plant. g	Number of per plant. m²	1000- seed weight. g	Seed yield. kg ha?¹
2001-2002						
Previous crop						
Sunflower	86.2 b	31.4 b	1.48 b	609.2 b	43.6 b	4567.9 b
Alfaalfa	92.2 a	40.2 a	2.06 a	699.2 a	46.2 a	5114.9 a
Wheat cultivar						
Golia	67.5 b	32.2 b	1.39 b	590.9 b	38.8 b	4569.1 b
Pehlivan	111.0 a	39.4 a	2.15 a	717.6 a	51.0 a	5113.6 a
Nitrogen Doses						
0	76.3 d	34.6 c	1.71 c	503.9 e	43.4 c	3758.8 c
50	86.6 c	35.6 b	1.77 b	599.1 d	44.8 b	4625.2 b
100	91.6 b	36.2 ab	1.79 b	635.8 c	45.3 b	4828.4 b
150	92.8 b	36.9 a	1.84 a	790.5 a	46.5 a	5612.7 a
200	98.8 a	35.9 b	1.74 bc	741.8 b	44.6 b	5381.8 a
2002-2003						
Previous crop						
Sunflower	76.7 b	30.1 b	1.21 b	536.0 b	44.0 b	3474.1 b
Alfaalfa	82.8 a	32.9 a	1.32 a	615.0 a	46.2 a	4455.6 a
Wheat cultivar						
Golia	59.9 b	30.9 b	1.10 b	546.4 b	38.8 b	3209.3 b
Pehlivan	99.7 a	32.9 a	1.43 a	604.5 a	51.4 a	4720.4 a
Nitrogen Doses						
0	67.4 e	29.9 c	1.12 c	433.4 e	43.3 c	2842.9 e
50	77.1 d	30.7 c	1.24 b	523.8 d	44.8 b	3556.0 d
100	81.5 c	32.4 b	1.29 ab	530.5 c	45.6 b	4164.9 c
150	85.1 b	33.7 a	1.39 a	560.6 b	46.6 a	4400.0 b
200	87.7 a	32.8 ab	1.29 ab	679.1 a	45.3 b	4860.5 a
Two-years average						
Previous crop						
Sunflower	81.5 b	31.2 b	1.34 b	572.6 b	43.8 b	4021.0 b
Alfaalfa	87.5 a	36.5 a	1.67 a	657.1 a	46.2 a	4785.2 a
Wheat cultivar						
Golia	63.7 b	32.6 b	1.24 b	568.6 b	38.8 b	3889.2 b
Pehlivan	105.3 a	35.2 a	1.79 a	661.0 a	51.2 a	4917.0 a

(continued)

Table 1 (continued)

Nitrogen Doses						
0	71.9 e	32.2 d	1.41 d	468.7 e	43.4 d	3300.8 d
50	81.8 d	33.1 c	1.50 c	561.4 d	44.8 c	4090.6 c
100	86.5 c	34.3 b	1.54 b	613.1 c	45.4 b	4496.7 b
150	89.0 b	35.3 a	1.61 a	720.6 a	46.5 a	5006.3 a
200	93.3 a	34.3 b	1.51 bc	710.5 b	45.0 bc	5121.2 a

crop and by the N level. The tallest plants were obtained from alfalfa plots. Wheat grown in plots that previously grew alfalfa was more affected than wheat grown in sunflower plots.

The plants were consistently taller in plots fertilized with N, as N enhanced vegetative growth. The largest plant height, with a statistically significant increase over other N treatments, was obtained from the 200 kg N ha^{-1} treatment, with an average of 98.8 cm in 2001-2002, 87.7 cm in 2002-2003, and 93.3 cm in the two years.

The lowest numbers of plant per m^2 were obtained in all years from the plots following sunflowers. As expected, the number of plants per m^2 increased with increasing N application. However, the largest number of plants per m^2 was obtained at the 150 kg N ha^{-1} fertilization rate in 2001-2002 and the average of the two years. The average number of established stands, the number of mature plants, was 721 at the highest N rate compared with 469 at the lowest N rate in combined years.

The 1000-seed weight was lower for wheat after sunflowers than for wheat after alfalfa. The highest 1000-seed weights were obtained from the 150 kg N ha^{-1} level. This level was consistently higher than for 200 kg N ha $^{-1}$ fertilization. Seed yield is the product of seeds per plant, the number of plants per m^2 and the 1000-seed weight (Norwood, 2000).

Winter wheat tended to produce greater seed yield when fertilized with high N levels. Also, the amount of N applied affected yield markedly. The response of seed yield was statistically significant, with increases as N application increased to 100 and 150 kg N ha^{-1} (Table 2). However, there was no statistically significant difference between the 150 and 200 kg N ha^{-1} N levels, both in 2001-2002 and the two years combined. Higher yields were obtained in the first growing period (2001-2002) than in the second growing period (2002-2003), presumably due to the weather. It is well-known that drought can cause a reduction in spike development, seed number and seed size in wheat. In a Mediterranean-type environment, the rapid onset of high temperatures and water deficit in late spring (during pollination and/or the seed-filling stage) can depress development of spikes and seeds. Weather effects on N response played a more important role in determining wheat yields than the previous crop cover. The reduction in seed yield following all crops in the dry year of 2002-2003 was parallel to reductions in the number of seeds per plant, the seed weight per plant and the number of plants per square meter. In general, seed yields and all yield components for Pehlivan tended to be greater than those of Golia in individual years and the two years combined. The highest seed yields were obtained for Pehlivan, with 5113.6 kg ha^{-1} in 2001-2002, 4720.4 kg ha^{-1} in 2002-2003, and 4917.0 kg ha^{-1} average over the two years. The seed yield of wheat following sunflower were consistently less than wheat after alfalfa, both in individual years and averaged across years and with different N levels. A perception exists that crops such as sunflower deplete more water from the soil profile and reduce yield of following crops. This depletion of water was confirmed (Hattendorf et al., 1988; Jaafer et al., 1993; Norwood, 1999), but its effect on the following crop has not been studied extensively. Groffman et al. (1987) reported that although N derived from a legume cover crop (*Trifolium incarnatum* L.) residue was sufficient for the following cereal crop, it was available at a slower rate than chemical fertilizers because of the dependence of legume N mineralization on residue decomposition

(Varco et al., 1993). Guy and Gareau (1998) found legumes such as dry pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik.) to be beneficial rotational crops prior to winter wheat.

According to our results, the optimum N rate for wheat yields was 150 kg N ha^{-1} in Mediterranean-type climatic conditions. Applying 150 kg N ha^{-1} produced a greater seed yield than with the high (200 kg N ha^{-1}) and other (0, 50, 100 kg N ha^{-1}) rates. In all years, the lowest seed yield was associated with no nitrogen treatment. Although seed yield increased as the amount of N increased, a leveling off or decline in yields occurred, indicating that optimum N rates were reached in this study.

Conclusions

The results of the present research, although occurring in a single year that was characterized by Mediterranean-type pattern, provide some indications of the trends that may occur in an agricultural system where fertilizer inputs need to be constrained. In particular, (i) the previous leguminous crop (alfalfa) positively influenced the seed of winter wheat as compared to a non-leguminous one (sunflower); (ii) in seed yield of wheat after alfalfa and after sunflower, there was observed a positive response to nitrogen fertilization on this fertile soil; and (iii) there were significant interactions in seed yield between the previous crop and N fertilization. These interactions, if confirmed in subsequent years, will guide farmers towards the choice of the best crop systems for their particular farm fertility level. Although sunflower reduced the subsequent yield of wheat, it may prove beneficial when the yield and economics of the whole cropping system are considered. The amount and seasonal incidence of rainfall play important roles in determining the response of wheat to carryover effects from the previous crop and to the rate of nitrogen fertilization. Low rainfall reduced the grain yield, which ranged between 393 kg ha^{-1} in Pehlivan and 1360 kg ha^{-1} in Golia.

Acknowledgments

The authors wish to thank American Journal Experts for editing and English proofreading of the manuscript. The authors also thank Uludag University for editing and English proofreading service support.

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Received December, 22, 2009; accepted for printing September, 2, 2010.