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Effects of nitrogen treatment methods on yield, nitrogen loss and nitrogen uptake efficiency of wheat cultivars

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ABSRACT

Raised bed planting system has widespread application in irrigated agriculture of several countries because of the advantages of the system provided in soil tillage, water use and production costs. This study was conducted by Transitional Zone Agricultural Research Institute in Eskisehir and Selçuk University between the years 2007-2010. Bed planting system was used in this study and the effects of spring nitrogen (N^{15}- enriched urea) treatment methods (broadcasting and sub-surface application) on yields, nitrogen losses and nitrogen uptake efficiencies of two different wheat cultivars (Bezostaja1 and Alpu2000) were investigated under irrigated conditions. While treatments did not have significant effects on Bezostaja 1, they improved nitrogen uptake efficiency of Alpu2000. Nitrogen loss was 66.5% in control treatment of Alpu2000 and the value decreased to 49.2% with sub-surface nitrogen treatments. As compared to broadcasting treatments, 17.3% less nitrogen loss was achieved in sub-surface treatments. While nitrogen uptake efficiency was 19.9% in control treatments, the value reached to 33.4% with sub-surface treatments. Nitrogen uptake efficiency of sub-surface treatments was 13.5% higher than broadcasting treatments. It was concluded for bed planting system that sub-surface nitrogen treatments in spring significantly improved nitrogen uptake efficiencies and reduced nitrogen losses.

1. Introduction

In recent years, bed planting has been adopted in many countries, especially in Mexico. However, it is a quite new method in Turkey and has become a research topic recently. It seems to be a promising method only under irrigated conditions. One of the biggest advantages of this system is that it allows ma-

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chine weed control in spring and with the same operation applied nitrogen is incorporated into the soil. There are some research findings indicating improved nitrogen use efficiencies with such systems (Fahong et al 2004). It is known that when the nitrogenous fertilizers were applied to soil surface (broadcasted) in spring, great losses are encountered through evaporation (Mc Innes et al 1986). However, when such fertilizers were incorporated into the soil (sub-surface application), nitrogen losses through evaporation is greatly limited, nitrogen utilization efficiency is enhanced and ultimately several economic benefits are achieved (Rao & Dao 1996; Fahong et al 2004).

Smil (1997) indicated that nitrogen use efficiencies could be improved and less fertilizer could be used through more suitable application methods. However, under dry farming conditions, nitrogen uptake rates of wheat are usually below 50% due to significant evaporative losses when nitrogenous fertilizers were broadcasted over the soil surface (Fillery & McInnes 1992). Especially when urea fertilizer is broadcasted without incorporated into the soil, ammonia-type evaporative losses can exceed 40% (Fowler 1989; Hargrove et al 1977), and it has been reported that these losses were generally more at high temperatures, high pH levels and stubble deposits (Raun & Johnson 1999).

The primary objective of this study was to reduce nitrogen losses applied in spring season by increasing nitrogen uptake efficiency under irrigated conditions with bed planting system.

2. Materials and Methods

The present study was conducted between the years 2007-2010 to investigate effects of seasonal nitrogen fertilizer management systems on yield, nitrogen loss and nitogen uptake efficiencies of bread wheat cultivars under Eskisehir conditions. Two bread wheat cultivars [red hard (Bezostaja 1) and white semi-hard (Alpu2001)] were experimented under irrigated conditions.Two different nitrogen treatment methods (broadcasting and sub-surface) were used to apply nitrogenous fertilizers. Experimental layout was factorial in randomized complete block design with four replications.

Two year experimental data were evaluated in this study. Experiments were carried out on the experimental fields of Transitional Zone Agricultural Research Institute in Eskişehir. Bed planting system was used in sowings. Each plot had 3 sowing beds 70 cm apart, 6 m long and 0.70 m wide (2.1 x 6 = 12.6 m^2). Two rows were sown in each bed. Only 5 m sections of 2 beds were harvested (1.4 x 5 = 7 m^2) ~~as~~ to eliminate side effects. 350 grains m^{-2} sowing density was used based on results of previous studies. In present study, a pilot plot was treated with N^{15} treatments, 2 m of experimental plots was treated with N^{15}-enriched urea and the rest was treated with normal urea fertilizer. Both treatments were applied on the same day to eliminate the effects of timing and control treatment was performed right after mechanization. Monitoring technique was used to see the fate of nitrogen and evaluate the efficiency of the method, in other words, the effect of N^{15} use. Calculations were performed under the consultancy of TAEK experts (Halitligil et al 2002; Faust H 1981). N^{15} was also used in control plots to compare the efficiency of both methods. Nitrogen quantities were not considered as a factor in experiments and 150 kg N ha^{-1} ,recommended for irrigated conditions of the region, was used. Half of this nitrogen was applied at sowing as a normal, not N^{15} –enriched form, fertilizer and the other half was applied as N^{15} – enriched fertilizer as described above.

Long-term and experimental year precipitation data are provided in Table 1.

Table 1

Precipitation data (2007-2010).

YEARS	September	October	November	December	January	February	March	April	May	June	July	August	Annual Total (mm)
Long-term	14,7	25,2	30,6	45,6	38,4	32,6	33,3	35,0	42,1	29,3	13,8	6,5	347
2007-08	0,0	19,2	92,4	49,9	15,7	1,0	42,4	38,5	11,7	9,3	0,0	5,5	286
2008-09	30,7	6,4	49,6	34,5	66,3	82,0	40,9	28,0	15,4	10,2	19,4	2,0	385
2009-10	7,1	9,0	29,5	65,1	36,0	42,8	32,6	23,9	20,7	79,0	7,4	0,9	354

Soil characteristics of the experimental site are provided in Table 2. As can be inferred from the table, soils had low nitrate nitrogen levels.

Table 2

Soil characteristics of the experimental site (0-30 cm).

Soil Characteristics	Unit	2007-08	2009-10
Texture class		Clay	Clay
pH (1:2.5, Soil:Water)		7.83	7.54
EC (salinity) (1:5,	(µS/cm)	156.1	230
$CaCO_3$ (Lime)	(%)	10.9	8.0
Organic Matter	(%)	1.13	1.77
Phosphorus (P)	mg kg^{-1}	33.3	27.8
Potassium (K)	mg kg^{-1}	671,8	493
Calcium (Ca)	mg kg^{-1}	3764,1	6076
Magnesium (Mg)	mg kg^{-1}	216,7	433
Sodium (Na)	mg kg^{-1}	33,6	40
Boron (B)	mg kg^{-1}	1.44	1.39
Cupper (Cu)	mg kg^{-1}	1.28	1.34
Iron (Fe)	mg kg^{-1}	2.44	4.21
Zinc (Zn)	mg kg^{-1}	0.37	0.44
Manganese (Mn)	mg kg^{-1}	6.13	3.76
Phenolsulphonic acid method (NO_3)	mg kg^{-1}	2,09	0,84
KCl extraction method	mg kg^{-1}	10,2	10,8

Experimental soils have clayey texture with low organic matter (1-2%) levels. Soils had either medium (5-15%) or high (15-25%) lime contents, slight alkaline reaction and were either saline or non-saline. Available B, Cu and Mn levels were sufficient, but Zn levels were insufficient (Lindsay & Norvell 1978). Zn was applied in spring through foliar applications in the first year and applied to soil at sowing in subsequent years, due to Zn deficiency in soils.

Data analysis Data were analyzed with JMP statistical software (JMP, SAS Institute, Cary, NC). General linear model (GLM) of the software was used for variance analysis. Student’s t-test was used to compare the means. Experimental data were also subjected to regression and correlation analyses.

3. Results and Discussion

Grain yields of treatments are provided in Table 3. Treatments did not have significant effects on grain yields of the first year, but only sub-surface nitrogen treatments had significantly higher yields than the control treatment in the second year. In present study, only the nitrogen treatment methods were compared, nitrogen doses were not compared. With regard to wheat cultivars (Bezostaja 1 and Alpu2000), treatments did not have significant influences on yields of Bezostaja 1, but sub-surface treatments influenced the yields of Alpu2000.

Since the total nitrogen (150 kg N ha^{-1}) used in experiments exceeded the nitrogen need of wheat in the first year, sub-surface treatments did not significantly influence grain yields. However, the treatments had significant effects in the last year since soil nitrogen levels of the last year were quite low. In the first year, wheat was sown after safflower exploiting soils, but it was sown after maize in the second year. Maize uptakes more nitrogen than safflower and such a decrease in soil nitrogen levels can clearly be seen in Table 2.

Table 3

Effects of spring nitrogen treatment method on yields of Alpu2001 and Bezostaja 1 under irrigated conditions

Year	Nitrogen Treatments	Grain Yield (kg/ha)		
		ALPU	BEZ.	ORT.
2007-08	Broadcasting	6070	4450	5260a
	Subsurface	5810	4590	5200a
	Mean	5940 a	4520 b	5230 A
2009-10	Broadcasting	3670	3440	3550 c
	Subsurface	4150	3770	3960 b
	Mean	3910 c	3600 d	3760 B
General Aveage	Broadcasting	4870	3950	4410
	Subsurface	4980	4180	4580
	Mean	4920 A	4060 B	4490
CV (%) = 5.7 Lsd (0,05) Cultivar=192**, Lsd (0,05) Treatment = N.S, Lsd (0,05) Cultivar X Treatment = N.S. Lsd (0,05) Treatment = N.S.				
Lsd (Year) = 192** Lsd (Yearxcultivar) = 271** Lsd (Year X Treatment) = 271** Lsd (Year X Treatment X Cultivar) = N.S.				

BEZ:Bezostaja 1

Nitrogen Uptake Efficiency Assessments Through The Use Of N^{15}

As can be inferred from Table 4, sub-surface nitrogen treatments did not have significant effects on total plant nitrogen yields of the first year. However, actual dimensions of plant nitrogen uptake can better be inferred from straw, grain and plant total nitrogen yields rather than total concentrations.

To calculate nitrogen uptake efficiency from the straw and grain nitrogen contents, initially these contents should be converted into straw and grain nitrogen yields, then to plant total nitrogen yield with the following equations;

STRAW YIELD (kg ha^{-1}) = BIOLOGICAL YIELD (kg ha^{-1}) – GRAIN YIELD (kg ha^{-1})

STRAW NITROGEN YIELD (kg ha^{-1}) = STRAW YIELD (kg ha^{-1}) x STRAW NITROGEN CONTENT (%)

GRAIN NITROGEN YIELD (kg ha^{-1}) = GRAIN YIELD (kg ha^{-1}) x GRAIN NITROGEN CONTENT (%)

PLANT TOTAL NITROGEN YIELD (kg ha^{-1}) = STRAW NITROGEN YIELD (kg ha^{-1}) + GRAIN NITROGEN YIELD (kg/ha^{-1})

Calculated plant total nitrogen yields from the above equations are provided in Table 4. As compared to the control treatment, sub-surface treatments increasedplant nitrogen uptake by 10 kg ha^{-1}. Nitrogen uptake values provided here indicated how much of total 150 kg nitrogen was up taken. On the other hand, to see the effects of nitrogen treatment methods on nitrogen uptake, only the N^{15} values applied in spring should be used. Following equations were used to get these values:

Table 4

Effects of nitrogen treatment methods on total nitrogen yields of Alpu2001 and Bezostaja1 wheat cultivars under irrigated conditions

Year	Nitrogen Treatments	Plant Total Nitrogen Yields (kg		
		ALPU	BEZ.	Aver.
2007-08	Broadcast-	157	132	144
	Sub-surface	158	141	149
	2007-08	157	137	147 A
2009-10	Broadcast-	79	86	82
	Sub-surface	100	92	96
	2009-10	90	89	89 B
General Average	Broadcast-	118	109	113 b
	Sub-surface	129	117	122 a
	2-year Av-	123 A	112 B	118
CV (%) =9.5 LSD (0,05) Cultivar =8.7* LSD (0,05) Treatment=8.7* LSD(0,05) Cultivar X Treatment =Ns				
LSD (0,05) Year= 8.7** LSD (Year X Cultivar)=12.0* LSD (Year X Treatment)=Ns LSD (Year X Treatment X Cultivar) = Ns				

Bez=Bezostaja 1

Following equations were used to get these values:

$$\text{N from Fertilizer N (\%) (\% Nff)} = \frac{\%\ ^{15}\text{N atom excess (in plant sample)}}{\%\ ^{15}\text{N atom excess (in applied fertilizer)}} \times 100$$

$$\text{N from Fertilizer N (Nff, kg ha}^{-1}\text{)} = \frac{\text{Plant nitrogen yield (kg ha}^{-1}\text{) x N from fertilizer N (\%)}}{100}$$

$$\text{Fertilizer Use Efficiency (\%) (FUE, \%)} = \frac{\text{N from fertilizer (kg ha}^{-1}\text{)}}{\text{Applied N (kg ha}^{-1}\text{)}} \times 100$$

The value called as Fertilizer Use Efficiency in these calculations was defined as Fertilizer Nitrogen Uptake Efficiency The % Nff values were calculated from the analyses results of TAEK. Calculated fertilizer nitrogen uptake efficiency values are provided in Table 5. As compared to the control treatment, sub-surface treatments had significant effects on fertilizer nitrogen uptake efficiencies of both years. As the average of two years, while nitrogen uptake efficiency was 19.9% in control treatment, the value increased by 33.4% with sub-surface treatments. In general, sub-surface treatments yielded 13.5% higher nitrogen uptake efficiency as compared to the control treatment. It was reported that 8-35% of total nitrogen uptake realized after pollination (Van Sanford & MacKown 1987). Current treatments significantly increased nitrogen uptakes in the first and the last year. In this study, fate of nitrogen not taken up by plants (either remained in soil or lost) was also investigated.

Table 5.

Effects of nitrogen treatment methods on fertilizer nitrogen uptake efficiency of Alpu2001 and Bezostaja1 cultivars under irrigated conditions.

YEAR	Nitrogen Treatments	Fertilizer Nitrogen Uptake Efficiency (%)		
		ALPU	BEZ.	Aver.
2007-08	Broadcasting	27	28	27.5 b
	Sub-surface	48	34	41.0 a
	Average	37.4 a	31.1 b	34.3 A
2009-10	Broadcasting	11.1	13.5	12.3 b
	Sub-surface	28.7	22.8	25.7 a
	Average	19.9	18.2	19.3 B
General Aveage	Broadcasting	18.8 c	20.9 bc	19.9 b
	Sub-surface	38.4 a	28.3 b	33.4 a
	2-year Aver.	28.7	24.7	26.7
CV (%) =24 Lsd (0,05) Cultivar=N.S Lsd (0,05) Treatment=5.1** Lsd (0,05) Cultivar X Treatment= 7.02*				
Lsd (0,05) Year=5.10** Lsd (Year X Cultivar)=N.S Lsd (Year X Treatment)=N.S Lsd (Year X Treatment X Cultivar) = N.S				

Soil samples were taken from 0-90 cm soil profile and analyzed for N^{15} quantities by TAEK. These values were then added to the quantities taken up by the plants. Resultant values were subtracted from the total amount applied to get the lost quantities (Table 6). The following equation was used for this purpose:

$$\% \text{ LOSS} = \frac{\text{USED N (kg ha}^{-1}) - (\text{UPTAKE N (kg ha}^{-1}) + \text{RESIDUAL N (kg ha}^{-1})}{\text{USED N (kg ha}^{-1})} \times 100$$

As it was in plant nitrogen uptakes, treatments had significant effects on nitrogen losses in the first and the last year and especially when Alpu cultivar was used. As the average of two years, while the nitrogen loss was 66.5% in control treatment, the value decreased to 49.0% in sub-surface treatments. About 17.5% difference in nitrogen losses was found to be significant.

Sub-surface treatments almost halved the nitrogen losses in the first year for Alpu. Nitrogen losses of cultivars are presented in Figure 1. Sub-surface treatments reduced evaporative losses and thus improved nitrogen use efficiencies and provided serious economic benefits (Rao & Dao 1996; Fahong et al 2004). It was reported that when the urea fertilizer was broadcasted over the field without incorporating into the soil, evaporative losses in ammonia form may go over 40% (Fowler 1989; Hargrove et al 1977) and such losses even get higher with high temperatures, high pH levels and straw cover over the soil surface (Raun & Johnson 1999). It was reported in previous studies carried out with N^{15} that nitrogen losses in cereals varied between 20-50% and such losses mostly realized through denitrification, evaporation and leaching (Olson & Swallow 1984; Karlen et al 1996).

Table 6

Effects of nitrogen treatment methods on nitrogen losses under irrigated conditions

YEAR	Nitrogen Treatments	Nitrogen Loss (%)		
		ALPU	BEZ	Average
2007-08	Broadcasting	60.3	55.5	57.9
	Sub-surface	36.3	48.3	42.3
	2007-08 Aver.	48.3	51.9	50.1
2009-10	Broadcasting	72.8	68.9	70.8
	Sub-surface	61.8	67.7	64.8
	2009-10 Aver.	67.3	68.3	67.8
General Average	Broadcasting	66.5	62.2	64.4
	Sub-surface	49.0	58.0	53.5
	2-year Average	57.8	60.1	58.9

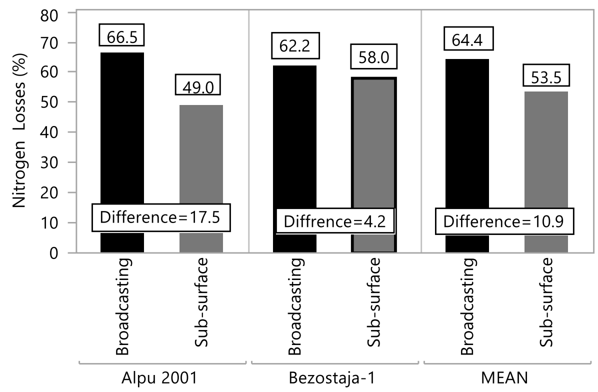

Figure 1. Effects of spring nitrogen treatments on nitrogen losses under irrigated conditions

Treatments did not have much effect on Bezostaja 1, but had significant effects on Alpu. The residual amount in soil did not varied much, in other words, the quantity not taken up by the plants was lost.

Conclusions

It is known that large losses of nitrogen are expected from broadcasting treatments under dry conditions. Therefore, irrigations were delayed for a while after treatment applications in this study not to prevent the losses totally. Similar to evaporative moisture losses, differences between the surface covers provided by the cultivars in early spring also influenced nitrogen losses. Nitrogen losses in broadcasting treatments varied between 50.1-67.8% and such large losses pointed out the economic significance of prevention of these losses. Losses in broadcasting treatments were mainly evaporative losses. Sub-surface treatments limited such losses, improved nitrogen use efficiencies and ultimately provided significant economic benefits. It was finally concluded that in bed planting system, sub-surface nitrogenous fertilization in spring significantly prevented nitrogen losses and improved nitrogen uptake efficiency of wheat cultivars.

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