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Effects of Different Previous Crops and Nitrogen Rates on Double Cropping Maize (*Zea mays* L.)

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The effects of previous crops (wheat, barley, lentil, Hungarian vetch and fallow) and different nitrogen rate (0, 120, 160, 200 and 240 kg N ha^{-1}) on grain yield and yield components of maize (*Zea mays* L.) were evaluated under irrigated conditions in Diyarbakir, Turkey in the 1999-2000, 2000-2001 growing seasons. Maize was grown in summers and wheat, barley, lentil and Hungarian vetch in winters. In the study, grain yield of maize varied between 6340.3 and 11598.9 kg ha^{-1}. It was determined that Hungarian vetch was suitable for previous crop and 160 kg ha^{-1} N rate is the best nitrogen rate in maize production. According to the interaction of previous crop-nitrogen rate, the highest yield was obtained from the subject grown after lentil and Hungarian vetch with 160 kg N ha^{-1}. Maize following legumes in rotation did not respond to applications over 160 kg N ha^{-1}, while barley-maize, wheat-maize increased at all levels of N applied. Fallow-sorghum did not respond to application over 200 kg N ha^{-1}.

Key Words: Maize, Yield, Nitrogen rate.

INTRODUCTION

Maize is one of the world's three most important cereal crops (the other two are wheat and rice) and it has the widest distribution of any cereal. The crop is primarily grown for its grain, which is consumed as human food. In some developed countries, maize is also grown for animal feed and as a base for industrial products such as oils, syrup and starch. Crop residues can be used as fodder, bedding, building materials and fuel[1].

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Crop sequences represent a system approach in crop production research, enabling the available natural resources to be preserved and more efficiently utilized. In crop rotation experiments, a monoculture is generally compared to various crop sequences. The fact that, in most cases, the yields of the cultivated crops are higher in crop rotation, as compared with a monoculture under identical conditions, is explained by the rotation effect. This rotation effect has been demonstrated irrespective of whether the crop rotation contains legumes or non-leguminous plants[2].

Crop rotations affect the amount of organic matter in soil. Previous crops have extensive rooting system, large amounts of organic matter in the soil when they die. Fallow periods in the rotations have been used in semi-arid regions of Turkey to conserve moisture for the succeeding crop. However, fallow exposes the soil erosion, which reduces the levels of organic matter and creates temperature and moisture conditions that speed up the rate at which soil organic matters decomposes.

Cropping systems are known to have residual effects on soil quality and the productivity of following crops. These effects have not been quantified for a range of cropping systems. Short-duration fallows with cover crops and legumes have shown to considerably increase succeeding maize yields[3]. Rotation experiments involving maize indicated grain yield responses to previous crops of 0.5-3.7 t/ha. Responses were equivalent to applications of fertilizer[4,5] N of 40-170 kg/ha.

Rational application of mineral nitrogen in arable farming is one of the most important issues today. On the one hand the obtained yields of different crops can be small if adequate amounts of nitrogen in soil are not available during the vegetation period, while at the same time, excessive fertilization can be very expensive and inefficient in economical and ecological sense.

Several studies have suggested that maize must have adequate amounts of N for profitable production. Maize usually responds[5,6] to fertilizer N.

The region, surrounded by South-eastern Taurus in the north and Syria and Iraq boundaries in the south, is defined as Fertile Crescent in chronicles. If we take into account the fact that the cultivation of cotton, which is an important crop in the fields irrigated or to be irrigated in the future will have a significant place and that the choice will be in favour of cotton/cotton or cotton/wheat, the second crop system after wheat can be considered to become established. Therefore, it is necessary to carry out the studies for extension of maize farming in the first instance. In order to be able to propose cotton farming as an alternative to previous-subsequent crop farming systems, the determination of the yield status of maize is of utmost importance after wheat, barley and lentil, which are widely cultivated in the region. Upon the extension of this system, these crops would be shifted to irrigated farming, leading to increases in yield and there would be a period of 120-150 d left that could be utilized.

This study was conducted to evaluate the effect of growing several previous crops and N rates on subsequent maize production.

EXPERIMENTAL

Field trials were conducted in the semi-arid region over three years (1999-01) at the Dicle University Agricultural Faculty, Trial area in Diyarbakir (37º54' N, 40º14' E altitude 660 m above mean sea level). Mediterranean and East Anatolian continental climates are dominant in this region (Table-1). The average annual temperature is 15.8 ºC, rainfall is 481.6 mm and the average relative humidity is about 53.8 %. The average temperature can reach 30 ºC in July and August. The lowest average temperature can be 7 ºC in December and January. The earliest frost in the region is usually at the end of October and the last frost around end of April. Nearly 98 % of annual rainfall in the region occurs from September to July. The highest humidity (70 %) occurs in winter, lowest (27 %) in summer. Some characteristics of soils (0-50 cm) in the experimental site were as follows: soil texture clay of soil (67 %), $CaCO_3$ 7.8 %, pH (H_2O) 8.1 and organic matter 1.5 %, with 6.2 and 205 mg kg^{-1} P and K, respectively[7].

Monthly rainfall data are given in Table-1. Nearly 98 % of annual rainfall in the region occurs from September to July (Table-1).

TABLE-1
MONTHLY RAINFALL DURING JANUARY 1999 THROUGH DECEMBER 2001 FOR DIYARBAKIR WITH 75-YEAR AVERAGE INCLUDED

Month	1999	2000	2001	1927-2002
January	15.6	70.9	14.9	73.5
February	45.5	58.2	72.4	67.1
March	52.0	30.7	126.1	67.9
April	76.1	33.0	54.0	70.5
May	22.4	6.1	86.9	42.1
June	1.1	0.3	0.0	7.0
July	0.9	0.0	0.0	0.7
August	0.0	0.0	0.0	0.5
September	10.5	0.9	0.0	2.7
October	2.7	35.1	67.0	31.1
November	1.9	34.0	52.2	54.0
December	31.5	113.6	131.7	71.5
Total	260.2	382.8	605.2	481.6

A field experiment was conducted, in which two winter legumes, two-winter cereal (non-legumes) and no previous crop (fallow) treatment were studied over 3 years. In addition, five fertilizer N rates were applied to subsequent maize. This irrigated experiment was conducted in Diyarbakir to evaluate double cropping maize after removal of wheat, barley, lentil, Hungarian vetch and fallow.

Experimental design was a split-plot randomized complete block design with three replications. The previous crops treatments were main plots and N rates were sub-plots. The sub-plot size was 2.8 m by 5 m. The cover crop treatments included fallow, wheat (*Triticum durum*, cv. 'Altintoprak 98'), barley (*Hordeum vulgare*, cv. Sahin 91'), Lentil (*Lens culinaris*, cv. 'Firat 87') and Hungarian vetch (*Vicia pannonica*, cv. Tigem common'). The N rates were 0, 120, 160, 200 and 240 kg N ha^{-1}, respectively. The cover crops were established each fall. Planting dates were 10 November, 18 November of 1999 and 2000, respectively. Fertilizer rates were 160 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} for wheat, 120 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} for barley, 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} for lentil, 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} for Hungarian vetch. Supplemental water was given twice to wheat and barley during stem elongation and heading period and once to Hungarian vetch and lentil during pod stage.

Previous crops were removed from the plot area by raking immediately prior to sowing. Maize variety 'LG 55' was planted in 70 cm rows with four rows. Plant population was approximately 71420 plants/ha^{-1}. Half of the N-ammonium nitrate and entire quantity (100 kg ha^{-1}) of P_2O_5 were applied at sowing and the remaining N-ammonium nitrate was top dressed 35 d after sowing. Plots were clean-weeded with the use of hands-hoes as two times. All plots were irrigated at 7-10 d intervals according to plant phonological throughout the season.

Plant height (to top of head) was measured for each plot immediately before grain was harvested. Grain yield adjusted to 14 % moisture was harvested from 1.4 m by 5 m area. 1000 seed weight, test weight, grain weight per con cob was determined from the harvested grain of each plot. The grain crude protein percentage was determined using Leco FP-528 protein analyzer.

Data were analyzed for statistical difference using analysis of variance (MSTAT-C programs, Version 2.1, Michigan State University, East Lansing, MI). Significant differences are given at 95 % probability level (LSD).

RESULTS AND DISCUSSION

The two measured parameters differed according to years (Table-2). The highest grain yield and crude protein content occurred during year 2000.

TABLE-2
MAIZE GRAIN YIELD, TEST WEIGHT, PLANT HEIGHT, 1000 SEED WEIGHT, GRAIN WEIGHT PER COB, CRUDE PROTEIN CONTENT AS AFFECTED BY YEAR, PREVIOUS CROPS AND N RATES

Year	Grain yield (kg ha^{-1})	Test weight (kg)	Plant height (cm)	1000 Seed weight (g)	Grain weight per cob (g)	Crude protein content (%)
2000	9935.9a	76.10	216.87	267.48	120.8	11.99a
2001	8909.1b	76.53	217.05	272.31	117.6	11.78b
Pre-Crop						
Wheat	8669.4c	74.98c	216.72	271.00a	109.14c	11.52c
Barley	8678.0c	74.47c	219.71	256.88b	115.02bc	11.76bc
Lentil	9842.7b	76.40b	218.66	272.43a	120.48ab	12.59a
Hungarian vetch	10597.0a	78.37a	218.19	278.54a	129.46a	11.92b
Fallow	9325.3b	77.37ab	211.53	270.62a	121.78ab	11.64bc
N rate (kg/ha^{-1})						
0	7614.2d	75.46	209.63b	263.42c	102.24d	11.05c
120	9077.1c	76.67	218.03a	266.12bc	116.93c	11.58b
160	10458.6a	77.13	221.10a	275.45a	129.30a	12.31a
200	10134.1ab	76.84	219.31a	273.85a	125.85ab	12.36a
240	9828.5b	75.50	216.74a	270.65ab	121.56bc	12.12a

Means within a column/row for a main effect followed by the same letter are not statistically different at the 0.05 probability level according to Least Significance Degree (LSD).

The highest grain yield, test weight, 1000 seed weight, grain weight per cob, crude protein were observed where maize followed Hungarian vetch. Significantly, lowest grain yield, test weight, grain weight per cob, crude protein was observed when maize followed wheat and barley. All parameters, except test weight, were affected by N rates. Higher yield, 1000 seed weight, grain weight per cob resulted from 160 kg/ha^{-1}. Grain yield increased with 160 kg/ha^{-1} but decreased with 200 and 240 kg/ha^{-1}.

Response of grain yield to N rate varied with previous crops. There were significant interactions between previous crops and N rates. The source of the interaction was differences in N response between different previous crops (Table-3).

Grain yield of maize varied between 6340.3 and 11598.9 kg ha^{-1} as average of two years according to previous crops × N doses interaction (Table-3). While the highest grain yield was obtained from 160 N ha^{-1} after lentil and Hungarian vetch, the lowest grain yield was obtained from 240 N ha^{-1} after lentil. Presumably, previous crops of lentil and Hungarian vetch created a soil environment more conducive to rapid maize growth and development than did other preceding crops. The effect of legume rotation

TABLE-3
EFFECTS OF DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON GRAIN YIELD (kg ha^{-1}) IN 2000, 2001

Previous crops	N rate (kg ha^{-1})					Mean
	0	120	160	200	240	
Wheat	6538.0jk	7659.7hij	9669.6b-f	9680.8b-f	9799.1b-f	8669.4c
Barley	6340.3k	7918.3ghi	9396.4c-f	9843.3b-f	9891.6b-f	8678.0c
Lentil	8679.4fgh	9743.0b-f	11598.9a	10064.6b-e	9127.6efg	9842.7b
Hungarian vetch	9399.2c-f	10795.5ab	11553.2a	10605.9abc	10631.4ab	10597.0a
Fallow	7114.2ijk	9269.1def	10074.7b-e	10475.8a-d	9692.7b-f	9325.3b
Mean	7614.2d	9077.1c	10458.6a	10134.1ab	9828.5b	
C.V.%	11.25					

Means within a column/row for a main effect followed by the same letter are not statistically different at the 0.05 probability level according to Least Significance Degree (LSD).

on yield of cereal appears to be primarily N effect, due to N supplied by legumes crops in the rotation[2,8-11]. Maize is generally producing more grain when grown in rotation than in continuous monoculture. Cereal-maize rotation showed a greater response to N-fertilizer than legume-maize rotation. Many previous studies reported that there were significant positive effects on legumes on yields of subsequent cereal crops as observed in this study[11,12]. Increased maize yield in legume based systems was organic residues and residual effect (legume effect). Anderson *et al.*[13] revealed that, except corn following switchgrass, 224 kg N ha^{-1} resulted in near maximal grain yields regardless of the previous cropping system. The highest corn also yields occurred following alfalfa. The highest grain yield (10430.8 kg ha^{-1}) for maize was obtained from lentil+maize crop rotation system in the South-eastern Anatolia region under irrigated conditions[14,15]. Anlarsal *et al.*[6] reported that the highest grain yield of maize (12910 kg ha^{-1}) was determined on the crop rotation of faba bean + vetch/maize applied 240 kg N ha^{-1}. The grain yield of maize also obtained from the berseem clover/maize and faba bean+vetch mixture applied 120 kg N ha^{-1} were 11470 and 11090 kg ha^{-1}, respectively. Ramteke and Sinha[16] reported that the highest corn yields occurred following clover, lower yield occurred after lentil, chickpea and pea, the lowest yield obtained after wheat. Saglamtimur *et al.*[17] reported that wheat is the most convenient previous crop for the second crop maize farming except for legumes, that low yields were obtained from maize cultivated following barley and canola and that this resulted from the fact that barley received more nutritients than wheat. In addition, Lampkin[18] reported that maize could be make up a good rotation with wheat, barley and legumes.

Grain yield increased with 160 kg/ha^{-1} but decreased with 200 and 240 kg/ha^{-1}. Many of the earlier fertilizer trials conducted on grain maize by Liu *et al.*[19], in the China, revealed that 120-180 kg ha^{-1} was optimum dose of nitrogen fertilization. Grain yields significantly increased with increasing fertilizer N application. In Germany, similar yield response to N supply was observed by Blankenau and Kuhlmann[20], who found a small decline in grain yield when 190-220 kg N ha^{-1}. Sharar *et al.*[21] concluded that N fertilizer should be applied 180 kg ha^{-1} to obtain higher grain yield of maize under Pakistani conditions. Therefore, the very high N application rate used in the area could not produce greater grain yields. N fertilization is likely to improve the nutritional quality of maize grain by improving crude protein content

Conclusion

Grain yield of maize varied between 6340.3 and 11598.9 kg ha^{-1} as average of two years (Table-3). While the highest grain yield was obtained from 160 N ha^{-1} after lentil and Hungarian vetch, the lowest grain yield was obtained from 240 N ha^{-1} after lentil.

The present results confirm that maize generally responds favourably to N fertilization and previous crops in Southern Anatolian Region. The N fertilizer requirement for maize production in this environment was found to be about 160 kg N ha^{-1}. N fertilization is likely to improve the nutritional quality of maize grain by improving crude protein content.

It was determined that lentil and Hungarian vetch are suitable for previous crop and 160 kg N ha^{-1} dose is the best nitrogen dose in corn production. According to the interaction of previous crop-nitrogen rate, the highest yield was also obtained from the subject grown after lentil and Hungarian vetch with 160 kg N ha^{-1}. Maize following legumes in rotation did not respond to applications more than 160 kg N ha^{-1}, while barley-maize, wheat-maize increased with all levels of N applied. Fallow-sorghum did not respond to application of more than 200 kg N ha^{-1}.

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