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Effect of Different Previous Crops and Nitrogen Rate on Grain Sorghum (*Sorghum bicolor* L. Moench)

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The effect of previous crops (wheat, barley, lentil, Hungarian vetch and winter fallow) and different nitrogen rates (0, 120, 160, 200 and 240 kg N ha^{-1}) on grain yield and yield components of grain sorghum (*Sorghum bicolor* L. Moench.) were examined under irrigated conditions in Diyarbakir, Turkey (subtropic) in 1999-2000, 2000-2001 growing seasons. Grain sorghum was grown in summers and wheat, barley, lentil and Hungarian vetch in winters. In the study, sorghum grain yield varied between 6833.8-9796.9 kg ha^{-1}. It was determined that Hungarian vetch is suitable for previous crop and 160 kg N ha^{-1} N rate was the best nitrogen rate in grain sorghum production. According to interaction of previous crop-nitrogen rate, the highest yield was obtained from the subject grown after lentil with 160 kg N ha^{-1}. Grain sorghum following legumes in rotation did not respond to applications more than 160 kg N ha^{-1}, while barley-sorghum increased at all levels of N applied. Wheat-sorghum, fallow-sorghum did not respond to application more than 200 kg N ha^{-1}.

Key Words: Grain sorghum, Yield, Previous crops, Nitrogen rate.

INTRODUCTION

Double cropping, the practice of growing two crops on a given area in one year, is an efficient use of land resources. Howard and Lessman[1] reported that double cropping soybean, sorghum after barley and wheat was the most successful multiple cropping system for grain production in the USA. Wheat, barley, lentil, Hungarian vetch may be used either as cash crop or as a cover crop to aid in reducing soil erosion.

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. This region called as Mesopotamia and situated between the rivers Tigris and Euphrates where a variety of culture crops have been taken into cultivation. In ancient times, irrigated agriculture is likely to have been conducted. However, withdrawal of water resources into deep valleys and thus agricultural production has decreased significantly. Accordingly, the region has experienced intensive emigrations. Sufficient amounts and distributions of precipitation are often the major limiting crop production factors in the Southern Anatolian region. This is especially true for main crops or double cropping situations since these factors have significant impact on yield and profitability. Where water is a limiting resource, as in the region, the objective of irrigation management has shifted from obtaining maximum grain yield *per se* to obtaining maximum grain yield per unit of supplemental water. Through the South Eastern Anatolia Region Project, about 1.7 million ha of agricultural area will be irrigated and a variety of crop species will be cultivated. In the areas where crops could be taken every year, or every alternate year, sustainable production will be achieved and significant increases would occur in vegetation production and related branches. Therefore, production increases to take place in irrigated areas and determination of cultivation turn of crop pattern to be grown under irrigated systems, in short, development of sowing rotation systems would gain importance.

Grain sorghum (*Sorghum bicolor* L. Moench) contributes substantially to world's total grain production, particularly in the tropics and subtropics. In those areas where it represents a major grain crop, it is generally difficult, if not impossible, to maintain soil fertility by using a short fallow or previous crops. The need to use inorganic fertilizer to achieve and sustain adequate soil fertility becomes important. Most of the soil of Turkey is inherently low in nitrogen, with nitrogen, being the most deficient. Good responses to annual fertilizer dressing have therefore been reported and only nitrogen is recommended for most crops in Turkey. Many of the earlier fertilizer trials conducted on grain sorghum varieties by Baytekin *et al.*[2] in the South Eastern Anatolia revealed that 200 kg ha^{-1} was optimum dose of nitrogen fertilization. Emeklier *et al.*[3] however reported it as 300 kg ha^{-1}. It is also obvious that inadequate fertilization is one of the factors that are limiting the yields of improved sorghum varieties now being cultivated[3-10].

Grain sorghum is similar to other cereal crops in that it generally produces more grain when grown in rotation than in continuous monoculture[11,12]. According to Hargrove[8], Grain sorghum did not respond to fertilizer N when following a legume cover crop but responded to as much as 99 kg N ha^{-1} when following a nonlegume cover crop or no cover crop. Rotation experiments involving sorghum indicated grain yield responses to legume crops of 30-350 %. The relationship between residue inputs and subsequent crop yield is mediated through increased mineral N supplying capacity of the soil[10]. The highest grain yield for grain sorghum was obtained from lentil-grain sorghum/cotton crop rotation system in the South eastern Anatolia region under irrigated conditions[13].

The objective of this study is to determine previous crops and N rates to grain sorghum under subtropic conditions.

EXPERIMENTAL

Field trials were conducted over three years (1999-01) at the Dicle University Agricultural Faculty experimental area in Diyarbakir (37º53' N, 40º16' E altitude 680 m above mean sea level). Subtropical climatic conditions are dominant in the region (Table-1). The mean annual temperature is 15.8 ºC, precipitation is 481.6 mm and the average relative humidity was about 53.8 %. The mean temperature can reach 30 ºC in July and August. Most rain falls in winter and there is almost no precipitation from July to September. The soils of the experimental area were thinly structured alluvial material or limestone. 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[14].

TABLE-1
CLIMATIC DATA OF DIYARBAKIR PROVINCE
1999-2001 YEARS AND LONG YEARS

Months	Mean temperature (ºC)				Precipitation (mm)				Relative humidity (%)			
	1999	2000	2001	Lon years	1999	2000	2001	Lon years	1999	2000	2001	Lon years
Jan.	4.5	1.3	4.0	1.7	15.6	70.9	14.9	73.5	71.0	74.0	68.0	76.0
Feb.	5.3	2.5	5.0	3.5	45.5	58.2	72.4	67.1	67.0	64.0	66.0	72.0
Mar.	8.1	7.0	11.4	8.1	52.0	30.7	126.1	67.9	65.0	51.0	69.0	65.0
Apr.	13.6	15.3	14.3	13.8	76.1	33.0	54.0	70.5	64.0	57.0	64.0	63.0
May	21.0	20.5	16.7	19.3	22.4	6.1	86.9	42.1	43.0	37.0	60.0	56.0
Jun.	27.3	28.0	26.7	25.9	1.1	0.3	0.0	7.0	31.0	21.0	26.0	37.0
Jul.	31.4	33.4	31.6	31.0	0.9	0.0	0.0	0.7	26.0	13.0	22.0	27.0
Aug.	30.6	30.4	30.2	30.3	0.0	0.0	0.0	0.5	27.0	20.0	25.0	27.0
Sep.	24.4	24.7	24.7	24.8	10.5	0.9	0.0	2.7	37.0	27.0	27.0	32.0
Oct.	17.6	16.7	16.3	17.0	2.7	35.1	67.0	31.1	43.0	47.0	50.0	48.0
Nov.	9.8	9.4	7.0	9.6	1.9	34.0	52.2	54.0	41.0	54.0	60.0	67.0
Dec.	4.8	4.3	5.1	4.1	31.5	113.6	131.7	71.5	66.0	79.0	61.0	76.0
Mean/ total	16.5	16.1	16.1	15.8	260.2	382.8	605.2	481.6	48.4	45.3	49.8	53.8

Source: Diyarbakir Province Meteorology Bulletin.

A field experiment was conducted in which two winter legumes, two winter nonlegume and no previous crop (fallow) treatment were studied over 3 years. In addition, five fertilizer N rates were applied to subsequent grain sorghum. This irrigated experiment was conducted in Diyarbakir to evaluate double cropping grain sorghum 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 (cover) treatments were main plots and N rates were subplots. 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'), 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. Grain sorghum variety 'DK 64 (DeKalb)' was planted in 70 cm rows with four rows. Plant population was *ca.* 125000 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 handshoes as two times. All plots were irrigated at 7-10 d intervals according to plant phenological throughout the season.

At physiological maturity plant height was measured. Other quantitative parameters were determined after harvest included grain (adjusted to 14 % moisture) and grain yield, grain weight per panicle, panicle weight. The grain crude protein percentage was determined using Leco FP-528 protein analyzer.

Data were analyzed using MSTAT-C programs, Version 2.1 (Michigan State University, East Lansing, MI). Significant level was set at 0.05. Means were separated by Least Significant Differences (LSD) tests.

RESULTS AND DISCUSSION

Plant height of grain sorghum was significantly influenced by previous crops according to the first year and two years analysis. However plant height was not influenced by N rate. The average plant height was 125.06 cm in 2000, 133.08 cm in 2001 and the 2 years average value was 129.08 cm (Table-2). In general, in grain sorghum grown following wheat and barley, significantly higher levels of plant height were determined as compared with other preliminary crops. In grain sorghum varieties developed suitable for mechanized harvesting, the plant height was not affected considerably[2]. This observation does not agree not with other research[7] in that plant height increased with N supply up to 60 kg N ha^{-1}.

TABLE-2
EFFECT OF DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON GRAIN SORGHUM PLANT HEIGHT (cm) AND PANICLE LENGTH (cm)

Previous crops	Plant height			Panicle length		
	2000	2001	Average	2000	2001	Average
Wheat	131.23 a*	134.80	133.02 a	23.24 ab	24.34 ab	23.94 a
Barley	129.05 a	134.55	131.80 a	24.04 a	24.68 a	24.36 a
Lentil	122.71 b	131.21	126.96 b	21.84 c	23.93 bc	22.89 b
Hungarian vetch	120.02 b	132.50	126.26 b	21.82 c	23.41 c	22.61 b
Fallow	122.28 b	132.32	127.30 b	22.20 bc	23.40 c	22.80 b
LSD 5% (pre- crop)	6.175	NS	3.536	5.57	0.7095	0.7719
N rate (kg ha^{-1})						
0	125.31	131.20	128.25	23.17	23.67	23.42
120	126.86	134.14	130.50	22.55	23.82	23.18
160	126.32	133.51	129.91	22.81	24.49	23.65
200	123.58	133.58	128.58	22.17	23.99	23.08
240	123.23	132.96	128.09	22.74	23.79	23.27
Mean	125.06	133.08	129.08	22.69	23.95	23.32
LSD 5% (N doses)	NS	NS	NS	NS	NS	NS
LSD 5% (Int.)	NS	NS	NS	NS	NS	NS
C.V. (%)	5.07	3.70	4.40	5.57	5.59	5.58

*Means within any columns followed by the same letter are not significantly different at the 0.05 level using Least Significant Difference (LSD) test.

Panicle length of grain sorghum was significantly influenced by previous crops according to the first and second years analysis (Table-2). Nevertheless, the panicle length was not influenced by N rate. The average panicle length was 22.69 cm in 2000, 23.95 cm in 2001 and the average of the two years value was 23.32 cm.

In general, in grain sorghum cultivated following wheat and barley, significantly higher panicle length was determined as compared with other previous crops. These findings are similar to those reported by Baytekin *et al.*[2].

Panicle weight of grain sorghum was significantly influenced by previous crops according to first and second years analysis (Table-2). Panicle weight were influenced by N rate according to first year and two years analysis (Table-3). The average panicle weight was 109.71 g in 2000, 113.90 g in 2001 and the two years average value was 111.80 g.

The highest grain yields per panicle were obtained from 240 N ha^{-1} after wheat. These findings show similarity with work of Ogunlela and Okoh[7].

Grain weight per panicle of grain sorghum were significantly influenced by previous crops and N rates. (Table-3). The average grain weight per panicle was 88.73 g in 2000, 99.40 g in 2001 and the two years average value was 94.07 g. The highest grain weight per panicle were obtained

TABLE-3
EFFECT ON DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON PANICLE WEIGHT (g) AND GRAIN WEIGHT PER PANICLE (g)

Previous crops	Panicle weight (g)			Grain weight per panicle (g)		
	2000	2001	Average	2000	2001	Average
Wheat	120.55a	112.72bc	116.63a	95.51a	97.65c	96.58a
Barley	107.45bc	111.93c	109.69c	84.59c	98.10c	91.34c
Lentil	111.60b	114.58ab	113.09b	88.82bc	100.52ab	94.67ab
Hungarian vetch	101.54c	116.55a	109.04c	83.29c	102.06a	92.67bc
Fallow	107.39bc	113.71bc	110.55bc	91.43ab	98.69bc	95.06ab
LSD5%(pre-crop)	6.218	2.262	3.041	6.379	1.97	3.069
N rate (kg ha^{-1})						
0	110.28ab	112.07	111.18b	88.22b	96.05c	92.13c
120	108.89b	113.31	111.10b	88.06b	98.65b	93.36bc
160	108.58b	114.91	110.25b	86.30b	100.95a	93.62bc
200	108.89b	114.12	111.50b	88.09b	100.61a	94.35b
240	114.88a	115.06	114.97a	92.96a	100.76a	96.86a
Mean	109.71	113.90	111.80	88.73	99.40	94.07
LSD 5% (N rate)	5.189	NS	2.865	3.211	1.634	1.774
LSD 5% (Int.)	11.60	5.889	6.406	7.179	3.10	3.966
C.V. (%)	6.41	3.13	4.99	4.90	2.23	3.67

*Means within any columns followed by the same letter are not significantly different at the 0.05 level using Least Significant Difference (LSD) test.

from 240 N ha^{-1} after wheat. Grain weight per panicle responded favourably to N supply in each of two years. This agrees with other research[7,15] in that N response is higher for sorghum rotations.

Crude protein content was significantly influenced by previous crops and N rates. (Table-4). The average protein was 11.49 % in 2000, 10.79 % in 2001 and the averages of two years value was 11.14 %. The highest grain protein was obtained from 160 N ha^{-1} after lentil (Table-5). There were significant interactions between previous crops and N rates. The highest crude protein was observed where sorghum followed lentil with 160 kg N ha^{-1}. The lowest crude protein was significantly observed when sorghum followed wheat and barley without N. Although higher crude proteins were determined in cultivations after Hungarian vetch and lentil as compared with other previous crops. Crude protein content increased with N supply (Table-5).

This agrees with other research[7] in that crude protein content increased with N supply. The protein percentages for interaction were close to 9.54-12.70 %. These values are higher to the critical protein range recommended by Cahill *et al.*[16].

TABLE-4
EFFECT OF DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON CRUDE PROTEIN AND GRAIN YIELD

Previous crops	Crude protein %			Grain yield (kg ha^{-1})		
	2000	2001	Average	2000	2001	Average
Wheat	10.66d	9.77d	10.22c	8519.9	8530.8	8525.4abc
Barley	11.11cd	10.25cd	10.68bc	8389.4	8438.9	8414.2bc
Lentil	12.20a	11.59ab	11.89a	7700.2	8629.6	8164.9c
Hungarian vetch	12.00ab	11.61a	11.80a	8781.7	9101.5	8941.6a
Fallow	11.48bc	10.74bc	11.11b	8747.9	8751.2	8749.6ab
LSD5%(pre-crop)	0.6479	0.8641	0.4963	NS	NS	502.1
N rate (kg ha^{-1})						
0	10.79c	10.07b	10.43c	7273.6c	7530.5d	7402.0d
120	11.38b	10.67a	11.02b	8766.5ab	8734.5c	8750.5bc
160	11.51ab	11.12a	11.32ab	9307.7a	9202.1a	9254.9a
200	11.84ab	11.07a	11.46a	8671.2ab	9118.2ab	8894.7ab
240	11.93a	11.04a	11.48a	8120.3b	8866.7bc	8493.5c
Mean	11.49	10.79	11.14	8427.9	8690.4	8559.1
LSD 5% (N rate)	0.4771	0.4822	0.3338	731.9	271.9	398.3
LSD 5% (Int.)	NS	NS	0.7464	1704.0	608.1	890.6
C.V. (%)	5.63	6.05	5.83	12.25	4.24	9.06

*Means within any columns followed by the same letter are not significantly different at the 0.05 level using Least Significant Difference (LSD) test.

TABLE-5
EFFECT OF DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON CRUDE PROTEIN % (AVERAGE OF 2 YEARS)

Previous crops	N rate (kg ha^{-1})					Mean
	0	120	160	200	240	
Wheat	9.54k	9.80jk	10.00ijk	10.59ghi	11.15d-h	10.22
Barley	9.68k	10.45hij	10.58ghi	11.11e-h	11.59b-f	10.68
Lentil	11.33c-g	11.85b-e	12.70a	11.93bc	11.66b-f	11.89
Hungarian vetch	11.51b-f	12.09ab	11.99abc	11.77b-e	11.64b-f	11.80
Fallow	10.08ijk	10.91fgh	11.32c-g	11.87bcd	11.37b-f	11.11
Mean	10.43	11.02	11.32	11.46	11.48	–
L.S.D 5%	0.7464	–	–	–	–	–

*Means within any columns followed by the same letter are not significantly different at the 0.05 level using Least Significant Difference (LSD) test.

The response of grain yield to N rate varied with previous crops. There were significant interactions between previous crops and N rates. The sources of the interaction differences in N response between different previous crops (Table-4).

Grain yield of grain sorghum varied between 6669.0 and 9796.9 kg ha^{-1} as average of two years (Table-6). While the highest grain yield was obtained from 160 N ha^{-1} after lentil, 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 conductive to rapid sorghum growth and development than did other preceding crops. The effect of legume rotation on yield of grain sorghum appears to be primarily N effect, due to N supplied by legumes crops in the rotation[7,8,15]. Grain sorghum generally produces more grain when grown in rotation than in continuous monoculture. Cereal-grain sorghum rotation showed a greater response to fertilizer N than legume-sorghum rotation.

TABLE-6
EFFECT OF DIFFERENT PREVIOUS CROPS AND NITROGEN DOSES ON GRAIN YIELD kg ha^{-1} (AVERAGE OF 2 YEARS)

Previous crops	N rate (kg ha^{-1})					Mean
	0	120	160	200	240	
Wheat	7400.4hi	8530.7d-g	8627.5c-f	9176.7a-d	8891.4bcd	8525.4abc
Barley	6833.8i	8518.7d-g	8720.9cde	8694.1cde	9303.4a-d	8414.2bc
Lentil	7730.0gh	8754.4cde	9796.9a	7874.3e-h	6669.0i	8164.9c
Hungarian vetch	7741.3fgh	8940.4a-d	9770.8ab	9236.3a-d	9019.1a-d	8941.6 a
Fallow	7304.6hi	9008.3a-d	9358.4a-d	9492.0abc	8584.6d-g	8749.6ab
Mean	7402.0d	8750.5bc	9254.9a	8894.7ab	8493.5c	–
L.S.D 5%	890.6	–	–	–	–	–

*Means within any columns followed by the same letter are not significantly different at the 0.05 level using Least Significant Difference (LSD) test.

This is consistent with other studies[2,5,10-12] in that N response and previous crops is great for sorghum rotations and production. Because, high yields can be maintained in the rotation and sorghum production without additions of fertilizer N.

The N fertilizer requirement for sorghum production in this environment was found to be about 160 kg N ha^{-1}. These results differ from earlier findings of previous researchers[3,4,8]. Soil conditions may have therefore, depressed sorghum yield response to N.

Conclusion

Among previous crops grain yield of sorghum ranged from 8164.9 to 8941.6 kg ha^{-1}. The yield was changed between 7402.0 to 9254.9 ha^{-1} as response of applied N doses. While the highest grain yield was obtained from 160 N ha^{-1} and lentil, Hungarian vetch and the lowest grain yield was obtained from 240 N ha^{-1} and lentil.

The present results confirm that grain sorghum generally respond favourably to N fertilization and previous crops in the Southern Anatolian region. The N fertilizer requirement for sorghum production in the environment was found to be about 160 kg N ha^{-1}. Application of N at any doses improved the nutritional quality of sorghum by enhancing crude protein contents of grains.

It was determined that Hungarian vetch is suitable as previous crop and 160 kg N dose is the best nitrogen dose in grain sorghum production. According to interactions of previous crop-nitrogen rate, the highest yield was obtained from the subject grown after lentil with 160 kg N ha^{-1}. Grain sorghum following legumes in rotation did not respond to applications more than 160 kg N ha^{-1}, while barley-sorghum increased with all levels of N applied. Wheat-sorghum, fallow-sorghum did not respond to application more than 200 kg N ha^{-1}.

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