Effect of Fertilization on Yield and Quality of Irrigated Yecora Rojo Wheat Grown in Saudi Arabia

A. AL-MASHHADI, M. NAEEM, and I. BASHOUR[1]

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ABSTRACT

Gross composition and rheological properties of flour from Yecora Rojo wheat grown under 12 different fertilization programs were investigated. A split-plot experiment of N and P fertilizer combinations with Fe, Zn, Cu, and Mn was conducted in a calcareous loamy soil in Al-Kharj, Saudi Arabia. Total applied rates were 125, 250, and 350 kg of N/ha, and 125 and 250 kg of P_2O_5/ha. The 250 kg N/ha and 125 kg P_2O_5/ha were sufficient to produce the highest yields. Addition of nitrogen increased the yield and the protein content. None of the treatments, however, affected adversely the flour milling yield, gross composition, and rheological properties.

Wheat is the major cereal crop grown in the Kingdom of Saudi Arabia. The total production of wheat in Saudi Arabia rose to 1.34 million tons in 1984, a rise of 65% over the previous year. The 1985 and 1986 harvests were 1.7 and 2.1 million tons, respectively. In 1984 the Kingdom exceeded self-sufficiency in wheat (Cheeseworth 1986). The wheat variety used in this study, Yecora Rojo, represents about 95% of the wheat grown in Saudi Arabia.

This study was initiated to investigate the effect of applying different rates of fertilizers on production of wheat and on flour milling yield, gross composition, and rheological properties. Fertilization management is known to affect the protein content and the baking quality of flour (Kemmler 1983).

MATERIALS AND METHODS

Field Operations

Seeds of Yecora Rojo wheat (130 kg/ha) were planted in 5× 6 m plots at the Regional Agriculture and Water Research Center (RAWRC) farm in Al-Kharj on November 12, 1984, and harvested on April 16, 1985. The growth stages of the crop are as follows: seeding (day 0), tillering (20 days), stem elongation (40 days), booting (70 days), anthesis (85 days), milk development (93 days), dough development (110 days), ripening (132 days), and harvest (155 days). The soil was a calcareous loam and classified as typic natragid, hyperthermic. The basic properties of the soil were determined as follows: sand, 49%; silt, 36%; clay, 15%; electrical conductivity of saturated extract, 5.4 mS/m; pH 7.5; $CaCO_3$, 23%; NO_3, 76 μg/g; $NaHCO_3$-extractable P, 5.7 μg/g; NH_4OAC-extractable K, 164 μg/g. The diethylenetriaminepentaacetic acid (DTPA)-extractable Fe, Zn, Mn, and Cu were 4, 0.7, 4.8, and 0.4 μg/g, respectively. The N-P-K fertility treatments were 125-125-100, 250-125-100, 350-125-100, 125-250-100, 250-250-100, and 350-250-100; the same treatments were repeated with micronutrients (Fe, Zn, Cu, and Mn). Three rates of N (125, 250, and 350 kg of N/ha) were supplied in four equal doses of urea (before planting, early tillering, early booting, and flowering stages). Two rates of P (125 and 250 kg of P_2O_5/ha) were supplied as triple super phosphate in one dose before planting. K was applied as potassium sulfate at a rate of 100 kg of K_2O/ha before planting to all treatments. Iron was added in one dose to the soil before planting as ethylenediaminedihydroxyphenylacetic acid chelates at a rate of 5 g of Fe/m^2. Zinc, manganese, and copper were added to the soil with iron before planting in one dose in the form of ethylenediaminetetracetic acid chelates at the rates of 5 g of Zn, 1 g of Mn, and 2 g of Cu/m^2. Each treatment was repeated four times in the field.

The method of irrigation was flood; irrigation water contained 2,870 μg/g of total dissolved solids. The plants were irrigated once every 8–12 days, depending on the weather and crop need. At harvest, both grain and straw yields were measured. A grain sample of about 7–10 kg from each plot was sent to the laboratory for milling and quality evaluation. No pesticides were used during the growing season because the crop was not infected with any diseases or insects that required chemical control.

Flour Milling

Forty-eight wheat samples were milled in a Buhler laboratory mill according to the procedures approved by the AACC (1983). Preparation and tempering at 16.5% moisture were done according to AACC method 26-10. Milling was done according to AACC method 26-20. Percentage of milling yield was calculated by taking the weight percentage of wheat flour to wheat milled. Straight flour was obtained by combining all streams. All wheat flour samples were stored at 5° C in tightly sealed plastic containers for further analysis.

Chemical Composition

Protein (N × 5.7) was determined according to AACC method 46-08, percentage of ash was determined according to method 08-01, and moisture of wheat and wheat flour were analyzed according to the procedures outlined in 44-15A (AACC 1983).

Rheological Analysis

Water absorption, arrival time, dough development time, stability, and mixing tolerance index of the wheat flours were done by using a Brabender farinograph equipped with the 300-g bowl and the constant dough weight procedure 54-21 (AACC 1983). Extensibility and resistance to extension were determined with the Brabender Extensograph according to the method described in method 54-10 (AACC 1983). Load extension curves were recorded at 45-, 90-, and 135-min rest periods. Only the final rest period values were used for comparing flour properties. Resistance to extension was divided by extensibility to obtain the ratio figure. Analysis of variance was done on an IBM computer using an SAS program (Statistical Analysis System, Cary, NC) for the evaluation of the obtained results.

RESULTS AND DISCUSSION

Grain and Straw Yields

The yields of grain and straw from each treatment are presented in Table I. The results indicated that treatments 2, 3, 5, and 6 gave the highest yields with no significant differences among the treatments. Therefore, maximum economical production was obtained when 250 kg of N and 125 kg of P_2O_5/ha were applied during the growing season. Supplying higher levels of N or P did not increase the yield of grain or straw significantly. The response of wheat to N and P fertilization was expected, because the soil is low in N and P and wheat crops grown in the same region responded to N and P fertilization significantly (Haykal and Sakir 1978).

Potassium was added to all treatments to ensure its availability

[1]Regional Agriculture and Water Research Center, Ministry of Agriculture and Water, P.O. Box 17285, Riyadh 11484, Saudi Arabia.

in sufficient amounts for the wheat crop. The addition of micronutrients affected neither the yield nor the quality of the harvested grain. Therefore, for simplicity, data obtained from treatments receiving micronutrients were not included in the reported results. Amounts of Fe, Zn, Cu, and Mn present in the soil are considered sufficient because the addition of these elements did not lead to any increase in the yield. These levels agree with the critical levels of micronutrients in calcareous soils as reported by Lindsay and Norwell (1978).

The results indicated that the 125 kg P_2O_5/ha level was sufficient for the crop under the condition of the experiment. The addition of higher amounts of P fertilizers (250 kg P_2O_5/ha) neither affected the yield nor the tested properties.

Flour Yield and Quality

The milling yield data are presented in Table I. The results indicated that there were no significant differences among treatments. The milling yield ranged between 65.4 and 67.8%. The increase in grain yield as a result of higher N fertilization from 6.8 to 7.78 ton/ha had no effect on the milling yield percent.

The baking quality was affected by climatic conditions of the wheat-producing region and by hereditary differences in the cultivated varieties.

Research results and practical experience have shown that skillful fertilizer management can lead to significant yield increases and quality improvements. Baking quality is influenced by the protein content (Kemmler 1983). Saudi Arabian Standards require that crude protein content of whole wheat flour be at least 12.5% (SASO 1979), and the protein content of each treatment was 13% or more (Table II). Increasing nitrogen from 125 to 350 kg of N/ha led to a significant increase in the protein content of wheat. Protein increased from 13 to 14.4% at the 125 kg/ha level of P_2O_5 and from 13.7 to 14.4% at the 250 kg/ha level. The difference in protein content between 250 and 350 kg of N/ha was not significant. Protein contents of the various treatments were similar to those reported by Watt and Merrill (1963) for hard red winter and spring wheat and by Pratt (1978) for pan bread. The protein in the flour was 1–1.3% less than that of the grain. The different fertilization treatments had no significant effect on the ash content of grain or flour. Ash in the grain ranged between 1.42 and 1.51% and in the flour between 0.57 and 0.60% (Table II).

The farinograph data for the flours obtained from the various treatments (Table III) show that flour water absorption ranged between 68.8 and 71.2%, averaging 70.2%. The dough development time ranged between 5.4 and 6.0 min, averaging 5.8 min. Stability results of flour indicated no significant differences among treatments (10.3–12.2., average 11.2 min). All values are higher than those reported by Pratt (1978) (9 min) for pan bread, soft or hard wheat, which indicated good bread wheat quality. The value of mixing tolerance index of treatment 5 (35 Brabender units [BU]) was significantly lower than the values of all other treatments (average 41.3 BU). However, all the results were in the range required for good quality bread. The arrival time of low nitrogen treatments (1.6 min) was significantly lower than that of the medium (2.2–2.3 min) and the high (2.4–2.6 min) treatments. Results indicate that there is a positive relation between protein content and arrival time.

The tests of extensigraph properties were performed on samples that exhibited proper farinographic behavior. Results of extensibility (E), in Table IV indicated that, similar to protein content of wheat and flour and arrival time of flour, E values of low nitrogen levels (193.4–200.2 mm) were significantly lower than those of the medium (195.2–206.2 mm) and high levels (210.1–215.4 mm).

The values of resistance to extension (RE) showed that there was no significant difference among treatments (311–346.1 BU). Also, there was no significant difference among the RE/E ratios, which ranged between 1.5 and 1.8, averaging 1.7.

Extensigraph results (extensibility, resistance to extension, ratio) indicated that the Yecora Rojo wheat has a medium strength (Pratt 1978). The farinograph and extensigraph results do not agree with the results reported by Khatchadourian et al (1985) for Yecora Rojo flour that was obtained from the Grain Silos and Flour Mills Organization, Riyadh. Such differences are expected to exist, since the flour samples in each study were obtained from grain samples that were produced in different years and grown under different climatic and management conditions.

TABLE I
Grain and Straw Yields and Milling Yield (%) of Various Fertilization Treatments of Wheat[a]

Treatment No.	Fertilization (kg/ha) N	P_2O_5	K_2O	Grain Yield (ton/ha)	Straw Yield (ton/ha)	Milling Yield (%)
1	125	125	100	6.80 c[b]	7.83 d	65.4 a
2	250	125	100	7.33 abc	8.71 abcd	66.4 a
3	350	125	100	7.26 abc	8.67 abcd	66.7 a
4	125	250	100	6.88 bc	7.99 cd	65.8 a
5	250	250	100	7.78 a	9.23 ab	67.8 a
6	350	250	100	7.70 ab	9.70 a	67.6 a

[a] Mean of four replicates.
[b] Means with the same letters are not significantly different.

TABLE II
Protein and Ash Content in Wheat Grain and Flour of Various Fertilization Treatments[a]

Treatment No.	Grain Protein[b,c] (%)	Grain Ash[b] (%)	Flour Protein[b,c] (%)	Flour Ash[b] (%)
1	14.2 b[d]	1.62 a	13.0 c	0.64 a
2	15.0 b	1.63 a	14.1 b	0.67 a
3	15.8 a	1.57 a	15.0 ab	0.65 a
4	14.9 b	1.55 a	12.9 c	0.68 a
5	14.9 ab	1.64 a	14.0 b	0.66 a
6	15.7 a	1.56 a	15.1 ab	0.64 a

[a] Means of four replicates each done in duplicate.
[b] Dry base.
[c] N × 5.7.
[d] Means with the same letters are not significantly different.

TABLE III
Farinograph Data for the Flours Obtained from Various Fertilization Treatments[a]

Treatment No.	Water Absorption (%)	Arrival Time (min)	Dough Development Time (min)	Stability (min)	Mixing Tolerance Index (BU)
1	68.8 c[b]	1.6 b	5.9 a	12.2 a	44 a
2	70.6 ab	2.2 a	5.9 a	11.8 a	39 a
3	69.5 bc	2.6 a	6.0 a	10.5 a	39 a
4	70.7 ab	1.6 b	5.4 a	10.6 a	45 a
5	71.2 a	2.3 a	5.9 a	12.1 a	35 b
6	70.3 abc	2.4 a	5.8 a	10.3 a	46 a

[a] Means of 4 replicates.
[b] Means with the same letters are not significantly different.

TABLE IV
Extensigraph Data for Flours Obtained from Various Fertilization Treatments[a]

Treatment No.	Resistance to Extension (RE) (BU)	Extensibility (E) (mm)	Ratio RE/E
1	334.4 a[b]	200.2 bcd	1.7 a
2	338.8 a	206.2 abcd	1.7 a
3	346.1 a	215.4 a	1.6 a
4	340.0 a	193.4 d	1.8 a
5	311.2 a	195.2 cd	1.6 a
6	311.0 a	210.1 a	1.5 a

[a] Means of four replicates each done in duplicate.
[b] Means with the same letters are not significantly different.

CONCLUSION

The results of the study indicate that the flour of Yecora Rojo wheat variety has desirable characteristics for breadmaking. The addition of 250 kg of N/ha increased plant growth and yield and improved some of the characteristics of wheat grain and flour quality. This effect was observed clearly on the protein content of wheat. Increasing amounts of added nitrogen fertilizer increased the protein content in wheat and flour and increased the arrival time values. No significant differences were obtained for ash and milling yield.

No significant differences were observed among treatments for the following flour characteristics: dough development time, stability, mixing tolerance index, resistance to extension, and RE/E ratios.

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