Iron, Zinc, Manganese, and Copper Content of Semidwarf Wheat Varieties Grown under Different Agronomic Conditions[1]

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ABSTRACT

The influence of variety, date of planting, spacing of plants, rate of nitrogen fertilization, and irrigation on the iron, zinc, manganese, and copper contents of wheat was studied. The correlation of mineral content and yield with protein content as well as the relations among the mineral elements were studied. There were significant correlations among iron, zinc, and copper. None of the correlations involving manganese were significant. Zinc showed a significant negative correlation to yield and a positive correlation to protein content. Iron and copper were also correlated negatively to yield and positively to protein content, but the correlations were not significant. The manganese level was independent of yield and protein content. Only irrigation and late planting, two treatments which increase soil moisture, resulted in higher levels of iron, zinc, and copper, but not of manganese, in wheat.

Middle Eastern diets are typically based on vegetable foodstuffs; cereals and legumes are important components of these diets. Tables of food composition giving trace-mineral contents of foodstuffs usually allow a wide range of values in order to account for variations attributable to different agronomic conditions. The magnitude and significance of such variations have not been critically studied and very few reports are available on this problem. Schrenk (1) studied some minerals in wheat grains. Czerniejewski et al. (2) examined the minerals of wheat, flour, and bread. Colwell (3) studied the effect of the rate of seed application on the yield and composition of wheat, but did not put emphasis on trace elements. Basargin and Peregudova (4) studied the effect of variety and area of growth on some elements in wheat. They reported that winter and spring wheats contained 2 to 18 p.p.m. copper and 16 to 37 p.p.m. manganese; the variation was attributed to variety and location.

The purpose of this study was to examine the effect of several combinations of agronomic practices, namely, variety, date of planting, spacing, rate of fertilizer application, and irrigation, on the iron, zinc, manganese, and copper content of wheat (*Triticum vulgare* L.).

MATERIALS AND METHODS

The wheat samples were obtained from experiments conducted at the Agricultural Research and Education Center of the American University of Beirut, located in the Beqa'a Plain of Lebanon. In one experiment the yield and protein content of two varieties of wheat, Najah and Mexipak, were studied under early and late planting dates and high and low seeding rates. The design of the experiment was a split-split plot with three replications. The results of this experiment are given

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in Table I. Wheat samples for analysis were obtained from two other separate experiments in which the yield and protein content of Najah, Mexipak, and Javal varieties of wheat were tested at low vs. high rates of application of nitrogen fertilizer and under irrigated vs. dryland conditions. The results of these two experiments are given in Table II.

Seeds and grains were ground and homogenized before drying and ashing. The samples were dried to a constant weight at 100°C. Ten grams of each dried sample was ashed (5) and the ash dissolved in 10 ml. of warm HCl (1 + 3). The solution was filtered into a 25-ml. volumetric flask and made to volume with distilled water. Proper dilutions were made before atomic absorption measurements. Maximum care was taken to prevent contamination. Throughout these experiments, stainless-steel, glass, or porcelain equipment was used. It was washed and soaked in HCl (1 + 3) solution and rinsed with demineralized distilled water. The distilled water used in dilutions was demineralized and the filter paper was ashless. An appropriate blank was employed to zero the atomic absorption spectrophotometer (Perkin-Elmer 303). Concentrations were determined by comparing the absorbance of each sample with appropriate standard curves.

RESULTS AND DISCUSSION

The level of iron in wheat was 27.0 to 64.8 p.p.m. (Tables I and II). The difference between the iron content of the two varieties was significant ($P<0.01$). Najah variety always contained more iron than Mexipak under similar agronomic conditions, possibly due to a higher capacity to store this element. This possibility was supported by the wider range of iron content under different conditions in Najah (29.0 to 64.8 p.p.m.) compared to Mexipak (27.0 to 30.6 p.p.m.). Date of planting significantly influenced the iron content of Najah wheat, whereas seeding rate did not. The iron content of Mexipak wheat was constant under the dates of planting and seeding rates employed in this experiment. In another experiment, the iron content of Javal variety was higher in irrigated compared to dryland conditions—59.4 vs. 35.0 p.p.m. (Table II). In this experiment the correlations between the iron content and the yield or protein content were not significant; R values were −0.57 and +0.52, respectively (Table III).

The zinc content of wheat ranged between 23.1 and 53.7 p.p.m. (Tables I and II). The zinc level in Najah variety was significantly higher than that of Mexipak. The seeding rates employed did not significantly influence the zinc content, whereas late planting tended to increase the level of zinc in wheat. The level of N-fertilizer application did not affect the zinc level in either wheat variety (Table II). The study on the Javal variety showed that irrigation tended to increase the zinc content in this variety (48.0 p.p.m. in irrigated land and 23.1 p.p.m. in dry land). The correlation coefficients of zinc content with protein level and yield were +0.88 and −0.93, respectively. These coefficients were significant at the 0.01 and 0.001 levels, respectively (Table III).

The manganese content of wheat was 51.1 to 67.5 p.p.m. (Tables I and II). These levels were fairly constant and were not influenced by any of the various agricultural practices employed in these studies. Correlation coefficients between the manganese content and protein level or yield were not significant.

The copper level in wheat was between 3.0 and 8.5 p.p.m. (Tables I and II). The

TABLE I. INFLUENCE OF VARIETY, DATE OF PLANTING, AND SEEDING RATE ON THE IRON, ZINC, MANGANESE, AND COPPER CONTENT OF WHEAT (values are means of three replicates)

Constituent	Najah Variety				Mexipak Variety			
	Early planting (Nov. 2)		Late planting (Nov. 21)		Early Planting (Nov. 2)		Late Planting (Nov. 21)	
	Seeding rate				Seeding rate			
	10 kg./du.[a]	18 kg./du.	10 kg./du.	18 kg./du.	10 kg./du.	18 kg./du.	10 kg./du.	18 kg./du.
Iron, p.p.m.	29.0	32.9	49.2	35.9	27.0	29.0	28.6	28.6
Zinc, p.p.m.	49.3	48.3	53.7	52.5	32.6	34.0	39.4	37.2
Manganese, p.p.m.	53.7	51.1	51.2	51.7	51.2	51.7	54.5	52.6
Copper, p.p.m.	5.1	3.0	8.5	5.8	4.9	4.5	5.4	4.4
Protein, %	13.81	14.15	15.38	15.52	11.69	11.76	13.26	13.53
Yield, kg./du.	324	283	291	286	676	620	409	458

[a] A dunum (du.) is equal to 1,000 $m.^2$

TABLE II. INFLUENCE OF VARIETY, RATE OF NITROGEN FERTILIZATION, AND IRRIGATION ON THE IRON, ZINC, MANGANESE, AND COPPER CONTENT OF WHEAT (values are means of three replicates)

Constituents	Najah (Irrigated)		Mexipak (Irrigated)		Najah (Dryland)	Javal (Dryland)	Javal (Irrigated)
	10 kg. N/du.[a]	30 kg. N/du.	10 kg. N/du.	30 kg. N/du.	8 kg. N/du.	8 kg. N/du.	20 kg. N/du.
Iron, p.p.m.	59.4	64.8	30.6	27.0	45.0	35.0	59.4
Zinc, p.p.m.	47.1	47.1	35.0	37.0	32.5	23.1	48.0
Manganese, p.p.m.	52.5	57.5	56.9	63.0	60.6	60.6	67.5
Copper, p.p.m.	5.0	5.1	5.1	4.6	6.0	5.1	7.0
Protein, %	14.3	14.6	11.7	11.5	...	...	...
Yield, kg./du.	390	530	396	595	235	219	390

[a] A dunum (du.) is equal to 1,000 $m.^2$

TABLE III. CORRELATION COEFFICIENTS BETWEEN THE LEVELS OF MINERAL ELEMENTS AND YIELD AND PROTEIN CONTENT IN WHEAT

	Mineral element, p.p.m.			
	Fe	Zn	Mn	Cu
Yield, kg./du.	−0.57	−0.93[a]	−0.12	−0.26
Protein, %	+0.52	+0.88[b]	+0.02	+0.26
Iron, p.p.m.	...	+0.72[c]	+0.04	+0.78[c]

[a] $P<0.001$.
[b] $P<0.01$.
[c] $P<0.05$.

level of this element in the Mexipak variety was about 5.0 p.p.m. and remained constant under the different treatments. The copper level in Najah variety, however, was highly variable and appeared to follow no consistent pattern. This might have been caused by problems in ashing. Mexipak wheat was readily ashed, whereas Najah wheat exhibited some "fusing" and resistance to ashing. Wet ashing might be a solution to this problem. Correlation of copper levels with protein content and yield of wheat gave R values of 0.26 and −0.26, indicating no significant correlation (Table III).

The correlation coefficients of iron level with zinc and copper levels were 0.72 and 0.78, respectively. Both correlations were significant ($P<0.05$). The manganese content of wheat was constant and independent of the other three elements.

These data indicated that the iron, zinc, and copper, but not manganese, levels in wheat responded in the same general manner to changes in agricultural practices. The iron, zinc, and copper contents of wheat were negatively correlated to yield and positively correlated to protein content. The zinc content was the most highly correlated to yield and protein content, followed by iron, then copper. The manganese level was independent of yield or protein level.

Date of planting and irrigation influenced the mineral composition of the wheat, whereas seeding rate and nitrogen fertilization were without effect. Late planting and irrigation significantly increased the iron and zinc contents but not those of copper and manganese. It is probable that late planting, which moved the growing period into the rainy season, and irrigation exerted their effect through increased soil moisture content. Support of this suggestion is the observation[2] that hydroponically grown wheat had a relatively high iron content.

[2] Walker, R. B. Personal communication (1970).

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