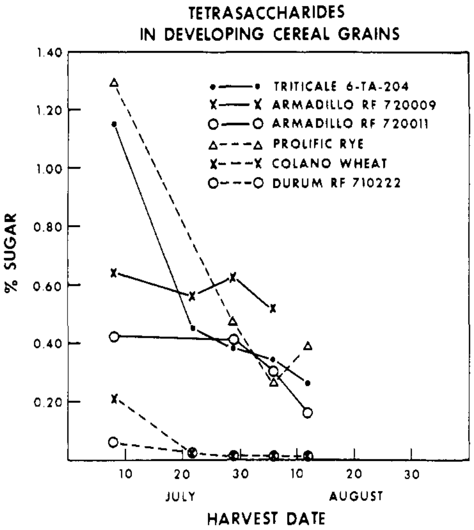

Figure 3. Tetrasaccharides (nystose and fructosylraffinose) in developing cereal grains.

maltotriose were present in triticales in very small amounts only, which was unexpected because of the reported high α-amylase activity in these grains. It is postulated that any starch degradation due to α-amylase activity is minimal. It is unlikely that kernel shriveling in triticale is a result of α-amylase degradation of starch.

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Differences in Concentrations and Interrelationships of Phytate, Phosphorus, Magnesium, Calcium, Zinc, and Iron in Wheat Varieties Grown under Dryland and Irrigated Conditions

Abdollah Bassiri*[1] and Aratoonnaz Nahapetian

Differences in concentrations and interrelationships of total P (TP), phytate P (PP), nonphytate P (NP), PP as percent of TP, Mg, Ca, Zn, and Fe, together with yield, in grains of eight Iranian ("Derakhshan, Harbash, Jawanjani, Jolgeh, Kalheidari, Koohrang, Ommid, and Roshan") and two foreign ("Penjamo and Tobari") varieties of wheat (*Triticum aestivum* L.) grown under dryland and irrigated conditions were determined. Highly significant differences were obtained among varieties and between the two irrigation treatments for most of the variables under study. When wheat varieties were grown under dryland conditions, the grain yield and the concentrations of TP and PP were significantly reduced while those of NP, Ca, and Mg were increased as compared with when grown under irrigation. Concentrations of the grain Zn and Fe did not seem to be affected by irrigation treatment. The four P variables (TP, PP, NP, and PP as percent of TP) were found to be highly correlated under both dryland and irrigated conditions. A high-yielding variety with low phytate and high mineral contents was suggested as ideal to be grown in either dryland or irrigated farming areas.

Phytate P is shown to constitute 49 to 80% of the total P in wheat grain (Knowles and Watkins, 1932; Booth et al., 1941; Asada et al., 1968; Nelson et al., 1968; O'Dell et al., 1972; Abernethy et al., 1973; Nahapetian and Bassiri, 1975, 1976). Phytic acid is present as a mixed insoluble salt of Mg, Ca, and K (Averill and King, 1926) and gradually releases the stored P during germination of the grain (Hall and Hodges, 1966; Asada et al., 1968; Williams, 1970).

There are numerous studies which show that phytic acid reduces the physiological availability of dietary Mg (McCance and Widdowson, 1942; Roberts and Yudkin, 1960; Likuski and Forbes, 1965), Ca (Harrison and Mellanby, 1939; McCance and Widdowson, 1942; Krebs and Mellanby, 1943; Hoff-Jorgensen et al., 1946; Cullumbine et al., 1950; Nelson et al., 1968; Berlyne et al., 1973; Reinhold et al., 1973b), Zn (O'Dell and Savage, 1960; Prasad et al., 1963; O'Dell, 1969; Reinhold, 1971, 1975a,b;

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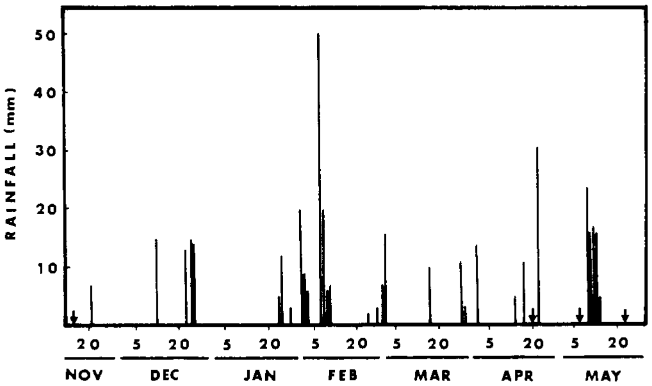

Figure 1. Distribution of rainfall at the site of experiment from planting to harvest time. Arrows indicate the date of irrigation for the irrigated treatment.

Halsted et al., 1972; Reinhold et al., 1973a), and Fe (Sharpe et al., 1950; Reinhold, 1975a).

Although the intake of Ca, Zn, and Fe is adequate in diets of Fars Villagers of Iran, incidences of deficiencies of these minerals have often been reported (Prasad et al., 1961; Halsted, 1968; Ronaghy et al., 1968; Ronaghy, 1970; Reinhold, 1971, 1975a,b; Haghshenass et al., 1972; Halsted et al., 1972; Reinhold et al., 1973a). These deficiencies have been mainly attributed to the low availability of Ca, Zn, and Fe due to excess of phytate in the predominantly cereal diets of villagers of this area (Reinhold, 1971, 1972, 1975a,b; Reinhold et al., 1973a).

In a survey of 112 villages of the Fars region, it was found that 60% of agricultural lands were under wheat cultivation, two-thirds of which were under irrigated and one-third under dryland wheat production (Bassiri, 1974). The mean grain yield for irrigated and dryland wheats were 1750 and 750 kg/ha, respectively. About 65% of wheat lands in this area were grown with the Roshan wheat variety (Bassiri, 1974).

Since wheat is such an important constituent of the diets of villagers and because our previous study (Nahapetian and Bassiri, 1976) had demonstrated that environmental factors could exert significant changes on concentration of most of the variables, this study was initiated to find the relative amounts and interrelationships of phytate and minerals in the grains of several wheat varieties produced under irrigated and nonirrigated growth conditions.

MATERIALS AND METHODS

Table I. Grain Yield of Ten Wheat (*Triticum aestivum* L.) Varieties under Dryland and Irrigated Conditions

Varieties (V)	Grain yield,[a] kg/ha Dryland	 Irrigated
Derakhshan	1031abc	1846ab
Harbash	958abc	2099ab
Jawanjani	807abc	1739ab
Jolgeh	756bc	1818ab
Kalheidari	896abc	1864ab
Koohrang	1084ab	2521a
Ommid	794bc	1940ab
Penjamo	752bc	1755ab
Roshan	1258a	1888ab
Tobari	578c	1401b
Av	891	1887
C.V.,[b] %	23.4	18.5
Irrigation (I) effect	**[c]	
V × I interaction effect	**[c]	

[a] Means in each column followed by the same letter are not significantly different at the 1% probability level (Duncan's test). [b] Coefficient of variability. [c] Significant at the 1% probability level.

Eight Iranian ("Derakhshan, Harbash, Jawanjani, Jolgeh, Kalheidari, Koohrang, Ommid, and Roshan") and two foreign ("Penjamo and Tobari") varieties of wheat (*Triticum aestivum* L.) were planted in two adjacent experimental fields at the College of Agriculture Experiment Station, Pahlavi University, Shiraz, Iran. The fields were kept fallow the preceding year and were not fertilized either previously or during the course of the experiment. The texture of the soil was silty clay with pH 7.7 and ECe 0.6 mmhos/cm. Available P ($NaHCO_3$ extract) and Ca (saturation extract) were 10 ppm and 4.1 mequiv/L, respectively, and the contents of Fe, Zn, and Mg (DTPA extract) were 1.35, 0.52, and 1.75 ppm, respectively. Planting was done on Nov 11, 1974 in a randomized complete block design with four replications in each field. Each plot consisted of six 5-m rows at 50-cm distance. Both fields received an irrigation soon after planting; however, one field was not irrigated thereon (dryland treatment) while the other was provided with water when necessary (irrigated treatment). At each irrigation time, each plot was uniformly supplied with about 10 cm of water. The amounts and dates of natural precipitation for both fields and the irrigation times for the irrigated treatment are shown in Figure 1.

The four middle rows of each plot were harvested at maturity (May 30, 1975) and the grains were weighed and a 500-g sample dried at 100 °C for 24 h, ground in a coffee mill, and stored in plastic bags until analysis.

Phytate P and total P concentrations were determined by a modification of the method described by Oberleas (1971) as reported in detail by Nahapetian and Bassiri (1975). Nonphytate P was calculated by subtracting the concentration of phytate P from that of total P of each individual sample. Concentrations of Ca, Mg, Zn, and Fe were determined on a Zeiss Model PMQII atomic absorption spectrophotometer, using the method of O'Dell et al. (1972).

Data for the characters in each irrigation treatment were subjected to the analysis of variance and means were compared using the Duncan's new multiple range test at the 1% probability level (Duncan, 1955). Combined data of both irrigation treatments were analyzed as a split-plot over space as described by Steel and Torrie (1960).

RESULTS

Yield of grain for the ten varieties under dryland and irrigated conditions are shown in Table I. There were great differences among varieties under each irrigation treatment; however, all varieties had consistently higher yields when irrigated. In fact, the overall average yield of all varieties under irrigation condition was more than twice that under dryland. Roshan and Harbash had the highest yields under irrigated and dryland conditions, respectively. The variation in yield was greater under dryland as when under irrigation as depicted from the coefficients of variability (C.V.). The results of statistical analysis shown at the bottom of Table I indicate highly significant differences between the two irrigation treatments and for the interaction of variety by irrigation treatment. This significant interaction merely points to the fact that varieties did not respond similarly to the two irrigation types.

Data on P are shown in Table II. The changes of average values for wheat varieties grown under dryland and irrigated conditions were, respectively, as follows: for total P, 333–396 and 363–449 mg/100 g; for phytate P, 142–276 and 303–355 mg/100 g; for nonphytate P, 80–236 and 21–119 mg/100 g; and for phytate P as percent of total P, 38–77 and 73–94%. In all cases, except for the total P in

Table II. Concentrations of Total P, Phytate P, Nonphytate P, and Phytate P as Percent of Total P in Grains of Wheat (*Triticum aestivum* L.) Varieties under Dryland and Irrigated Conditions

	Total P,^{a} mg/100 g		Phytate P,^{a} mg/100 g		Nonphytate P,^{a} mg/100 g		Phytate P as percent of total P^a	
Varieties (V)	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated
Derakhshan	361a	439ab	258a	320abc	103cd	119a	71ab	73c
Harbash	346a	421abc	266a	338abc	80d	83ab	77a	80bc
Jawanjani	372a	408abcd	142e	331abc	230a	77ab	38d	81bc
Jolgeh	392a	434ab	156cde	342ab	236a	92ab	40d	79bc
Kalheidari	370a	424abc	150de	355a	220a	69b	41d	84b
Koohrang	333a	363d	211b	342ab	122bcd	21c	63bc	94a
Ommid	352a	383cd	190bcd	303c	162b	80ab	54c	79bc
Penjamo	365a	422abc	268a	314bc	97d	108ab	73ab	74bc
Roshan	352a	395bcd	196bc	315bc	156bc	80ab	56c	80bc
Tobari	396a	449a	276a	340abc	120bcd	109ab	70ab	76bc
Av	364	414	211	330	153	84	58	80
C.V.,^{b} %	8.5	5.2	10.1	5.2	17.8	26.3	9.8	6.1
Irrigation (I) effect	*^{c}		**^{c}		**		**	
V × I interaction effect	ns^c		**		**		**	

^{a} Means in each column followed by the same letter are not significantly different at the 1% probability level (Duncan's test). ^{b} Coefficient of variability. ^{c} Significant at the 5% (*) or 1% (**) probability levels or not significant (ns).

Table III. Concentrations of Mg, Ca, Zn, and Fe in Grains of Wheat (*Triticum aestivum* L.) Varieties under Dryland and Irrigated Conditions

	Mg,^{a} %		Ca,^{a} ppm		Zn,^{a} ppm		Fe,^{a} ppm	
Varieties (V)	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated
Derakhshan	0.22a	0.14ab	1258ab	478a	44abc	43bc	80a	81a
Harbash	0.26a	0.13b	1552a	297a	44abc	41bc	71a	68a
Jawanjani	0.14b	0.15a	469c	277a	37bc	42bc	65a	61a
Jolgeh	0.14b	0.15a	844bc	422a	44abc	45bc	74a	59a
Kalheidari	0.12b	0.14ab	711c	247a	51ab	51ab	92a	89a
Koohrang	0.12b	0.15a	578c	330a	40bc	36c	56a	46a
Ommid	0.11b	0.15a	571c	236a	34c	38c	54a	58a
Penjamo	0.26a	0.14ab	891bc	207a	57a	46abc	66a	76a
Roshan	0.12b	0.13b	680c	222a	32c	39bc	60a	44a
Tobari	0.26a	0.14ab	1258ab	294a	50ab	57a	89a	59a
Av	0.17	0.14	881	301	43	44	71	64
C.V.,^{b} %	19.4	4.7	25.6	53.7	15.3	12.8	24.6	34.6
Irrigation (I) effect	**^{c}		**		ns^c		ns	
V × I interaction effect	**		**		ns		ns	

^{a} Means in each column followed by the same letter are not significantly different at the 1% probability level (Duncan's test). ^{b} Coefficient of variability. ^{c} Significant at the 1% (**) probability level or not significant (ns).

Table IV. Correlation Coefficients among Concentrations of Phytate P (PP), Nonphytate P (NP), Total P (TP), Phytate P as Percent of Total P (PP % TP), Mg, Ca, Zn, and Fe of Wheat (*Triticum aestivum* L.) Grains under Dryland (Lower Diagonal) and Irrigated (Upper Diagonal) Conditions

	PP	NP	TP	PP % TP	Mg	Ca	Zn	Fe
PP		−0.31	0.34^d	0.43^c	0.28	0.13	0.20	0.03
NP	−0.51^a		0.79^a	−0.99^a	0.02	0.14	0.50^b	0.30
TP	0.35^d	0.62^a		−0.70^a	0.20	0.22	0.63^a	0.32
PP % TP	0.70^a	−0.97^a	−0.45^b		0.04	−0.10	−0.44^b	−0.28
Mg	0.10	0.19	0.30	−0.17		0.04	0.14	−0.01
Ca	0.32^d	−0.05	0.23	0.11	0.67^a		−0.05	0.25
Zn	0.15	0.23	0.39^d	−0.17	0.57^a	0.32^d		0.45^b
Fe	0.25	−0.12	0.10	0.18	0.23	0.46^b	0.42^c	

^{a,b,c,d} Statistically significant at $P < 0.001$, $P < 0.005$, $P < 0.01$, and $P < 0.05$ level, respectively.

grains of varieties under dryland condition, highly significant differences were observed among the varieties for P constituents. The variation between varieties was greatest for nonphytate P and least for total P in grains of wheat grown under irrigated condition and consequently such grains had higher P as percent of total P. The nonphytate P was on the average about half in the grains produced under irrigation as compared with those produced under dryland condition. Among varieties, Tobari had the highest content of total P under both irrigation treatments. Koohrang under irrigation had 94% of its total P in the form of phytate P while in Jawanjani, produced under dryland, only 40% of the total P was present in phytate P. The interaction of variety by irrigation treatment was highly significant in all cases except for total P.

Data on the mineral constituents of the wheat grains are reported in Table III. No significant differences were found among the varieties for Fe under both irrigation conditions and for Ca in irrigated plots. The ranges of average values for wheat varieties grown under dryland and irrigated conditions, respectively, were as follows: for Mg, 0.11–0.26 and 0.13–0.15%; for Ca, 469–1552 and 207–478 ppm; for Zn, 32–57 and 36–57 ppm; and for Fe, 54–92 and

44–89 ppm. The effect of irrigation and the interaction of variety by irrigation treatment were highly significant for Mg and Ca and not significant for Zn and Fe.

The correlation coefficients between the variables for wheat varieties grown under dryland and irrigated conditions are shown in the lower and upper diagonals, respectively, of Table IV. The data can be grouped into three parts: correlations among P constituents, correlations among the minerals, and correlations among the P constituents and the minerals.

All correlations were significant among the four P variables under both growth conditions. The highest correlation was obtained between nonphytate P and phytate P as percent of total P. This correlation coefficient and those for phytate P and nonphytate P, and total P as percent of total P were negative, designating that an increase in one would cause a decrease in the other variable.

The significant correlation among the minerals were as follows: under dryland condition, all the four minerals were positively and significantly correlated with each other except for the variable pair Mg and Fe. In contrary, under irrigated conditions, no significant correlations existed between the minerals except for Zn and Fe.

Out of the 16 possible correlation coefficients between P constituents and minerals for each irrigation condition, only few were statistically significant. Phytate P was correlated with Ca at the 5% level of significance in dryland wheat. Nonphytate P had a high correlation with Zn in irrigated wheat. Total P was significantly interrelated with Zn under both irrigation conditions and with Fe only under irrigated treatment. Phytate P as percent of total P was negatively and significantly correlated with Zn under irrigated condition.

DISCUSSION

The data reported in this study indicate that great variations occurred in the constituents of wheat grains based on the amount of water supplied to the plant during the growing season. Although there was a good distribution of rainfall throughout most of the period of this study (Figure 1), the last two irrigations and particularly the one just prior to harvest which is the most critical time for grain maturation have been responsible for these great changes in the variables under study. In spite of a good amount of rainfall 16 to 20 days befor harvest, there was a great need for irrigation on May 22 due to hot and dry weather conditions. Unfortunately, such conditions are typical of many regions south of Iran where there is very little, if any at all, rainfall during the last part of spring and all summer months.

The yield of grain for nonirrigated, on the average, was more than half that of the irrigated varieties. These results are close to the average of the farm lands of the Fars region (Bassiri, 1974). It is interesting to note that the Roshan variety did comparatively well under both irrigation conditions and so it was a more stable variety. Varieties such as Roshan are especially fit in areas where farmers may depend mainly on natural precipitation to supplement the little amount of irrigation water they may have. This is probably the reason that 65% of the land under wheat cultivation in Fars region is planted with Roshan (Bassiri, 1974). This study also shows that varieties Koohrang and Derakhshan are also stable and high-yielding varieties under low or high water availability.

Reinhold (1975b) reported that the consumption of Lavash and Tanok (two common often unleavened bread types made from wholemeals of 95 to 100% extraction rates) was great in villages of Fars. Both of these breads are rich in phytic acid which might cause rickets by interfering with the absorption of Ca and perhaps P from the intestine and might be responsible for Zn and Fe deficiencies (Reinhold, 1972). A wheat variety low in phytic acid and high in minerals would definitely improve the general health of the villagers. This study shows that the lowest amount of phytate P as percent of total P was in the variety Jawanjani (38%) grown under dryland and in Derakhshan (73%) grown under irrigation (Table II). Under dryland farming, unfortunately, Jawanjani produced relatively low yields and had low contents of Ca and Zn. However, if Derakhshan were chosen for irrigated conditions, both its yield and mineral contents would be quite high (Tables II and III).

The present data clearly indicate that irrigation could exert significant changes on concentrations of total P, phytate P, nonphytate P, and phytate P as percent of total P. Increases in the amounts of total P in irrigated compared with dryland wheat grains could perhaps be explained by increased solubility of soil P and its availability to the plant as a result of irrigation during the grain maturation period. A greater proportion of the available P is converted into phytate P, rather than nonphytate P, as evidenced from our previous experiment (Nahapetian and Bassiri, 1975) where it was concluded that the rate of phytate synthesis in grains sharply increased starting with about 35 days before harvest. During this critical stage in seed development, in the present study, the varieties which received three irrigations before harvest produced higher contents of phytate P in their grains, as compared with nonirrigated varieties, due to higher availability of soil P to the plants and higher rate of phytate synthesis at this period.

Previous studies have shown that phytate P constitutes from 49 to 80% of total P of the wheat grain (Knowles and Watkins, 1932; Booth et al., 1941; Asada et al., 1968; Nelson et al., 1968; O'Dell et al., 1972; Abernethy et al., 1973; Nahapetian and Bassiri, 1975, 1976). In the present study, the ranges for the varieties under dryland were 38–77 and for those under irrigation 73–94%. Thus it can be argued that the range reported by other investigators may be widened by environmental conditions during the seed maturation period, by variety and maybe by other factors. In fact, in our previous study (Nahapetian and Bassiri, 1976) it was concluded that seasonal differences in environmental factors and the choice of agricultural practices might prove to be effective in decreasing the phytate content of wheat grain.

Total P and phytate P were highly correlated and showed a linear regression relationship in wheat grains (Nahapetian and Bassiri, 1976) and in beans (Lolas and Markakis, 1975). The correlation coefficients obtained between these two variables in this study under both irrigation conditions were also statistically significant. Other significant correlation coefficients between total P, phytate P, nonphytate P, and phytate P as percent of total P and the nonsignificant correlation coefficient between phytate P and Mg are in agreement with those reported earlier (Nahapetian and Bassiri, 1976) except that the signs of correlations are reversed for those between nonphytate P and phytate P and between total P and phytate P as percent of total P. Similarly, the significant correlations found between phytate P and Ca for the grains under dryland condition are in agreement with the values reported earlier for mature wheat grains (Nahapetian and Bassiri, 1975, 1976).

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Extractability, Solubility, and Molecular Size Distribution of Nitrogenous Constituents in Coastal Bermuda Grass

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Coastal Bermuda grass was extracted with buffer (pH 8.14) containing 0, 0.2, 0.5, or 1% sodium dodecylsulfate (SDS). The Bermuda grass was fractionated into insoluble residue (R_I), chloroplasts (R_{II}); and soluble fractions, high molecular weight (cut 1), polypeptides (cut 2), and low molecular weight (cut 3). At 0% SDS, total nitrogen (N_T) was cut 1 = 10.7 and 28.6% solubilized. Increasing percent SDS decreased percent N_T in the insolubles, and increased N_T in cut 1. At 1% SDS, the N_T was cut 1 = 35.6 and 55.8% solubilized. At 0% SDS, the protein of cut 1 was predominantly cytoplasmic, but at higher percent SDS, it was predominantly chloroplastic with some cytoplasmic. It had a broad molecular weight range (1 million to 2500). The gel chromatography average molecular weight for cut 1 ranged from 21 000 to 5000 and depended on the wavelength of detection (i.e., 206 or 254 nm) and on percent SDS. The protein extracted with SDS had more aromatic impurities than that extracted at 0% SDS and, when lyophilized first, was insoluble in 0.8 N NaCl. The two-stage extraction suggested would maximize the yield of protein suitable for humans and give two other fractions suitable for monogastric and ruminant animals, respectively.

Geometric growth in world population has increased interest in new sources of high-quality proteins for supplementing animal and human diets. In the last decade, several plants have been investigated, but alfalfa received the most attention (Pirie, 1971). The proteins in alfalfa have been partially characterized by various methods. For example, nitrogen has been determined in isolated fractions by the Kjeldahl method and by trichloracetic acid precipitation (Betschart and Kinsella, 1973), amino acids, by ion-exchange chromatography (Byers, 1971), and component proteins by gel chromatography (Sarkar et al. 1975; Knuckles et al., 1975). Grasses, particularly, those that fix CO_2 via the phosphoglyceric acid pathway (i.e., C-3 grasses), also have been investigated as sources of extractable protein. In contrast, little work has been done on the extractability, solubility, and molecular size dis-

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