Acta Botanica Hungarica 43 (3–4), pp. 403–421, 2001

EFFECT OF INDUSTRIAL EFFLUENTS POLLUTING THE RIVER NILE ON GROWTH, METABOLISM AND PRODUCTIVITY OF *TRITICUM AESTIVUM* AND *VICIA FABA* PLANTS

W. M. SHUKRY

Botany Department, Faculty of Science, Mansoura University Mansoura, Egypt;
E-mail: wafaa_12@yahoo.com

(Received 15 March, 2001)

Pot experiments using loamy soil were conducted to evaluate the effect of irrigation with industrial effluents on growth, uptake of nutrients and yield of wheat (*Triticum aestivum* Giza 164) as a monocot and faba beans (*Vicia faba* Giza 461) as a dicot plant. Also, irrigation by industrial effluents in combination with vesicular-arbuscular mycorrhiza (VAM) was used in trying to use a biological control to overcome the harmful effects of heavy metals pollution.

Irrigation of plants with industrial effluents leads to marked changes in growth criteria depending on plant and/or the stage of growth. Industrial wastewater led also to marked changes in total carbohydrates and nitrogen in both shoots and roots. On the other hand, combination of industrial waste water with VAM caused an increase in the total carbohydrates and total nitrogen in shoots and roots of both wheat and bean plants.

The yield components in wheat and bean were significantly increased with industrial effluents, but the biochemical concentrations were different. In wheat, the carbohydrate concentrations were increased, but protein-N and total-N were decreased, however mineral contents, especially Zn were increased. The reverse response was recorded with VAM. For bean the opposite occurred. Generally, bean plants were more sensitive to pollution with heavy metals, than those of wheat however this could influence be overcome by using VAM with irrigation.

Key words: industrial effluents, pollution, *Triticum aestivum*, vesicular-arbuscular mycorrhiza, *Vicia faba*

INTRODUCTION

The River Nile is known as a clean oligotrophic river. In the last decades it has been subjected to pollution via several and rather complicated routes. Agricultural and industrial effluents constitute a real threat to the River Nile system in Egypt (Abdel-Hamid *et al.* 1993). The potential toxicity of some positive effluents was partly related to their high content of heavy metals.

Heavy metal pollution of agricultural soils is one of the most severe ecological problems on a world scale. The biggest sources of pollution in Dakahlia are the discharges from manufacture of Talkha fertilisers. Vegetable production in this area results in contaminated products with excessive amounts of Zn.

Zn toxicity in many plant species is associated with the inhibition of root growth (Powell *et al.* 1988), or reduced in plant growth and N uptake due to its negative effect on P-uptake (El-Hamid *et al.* 1992). On the other hand, Zn-deficient plants of various species exhibit great permeability of the plasma membrane resulting in significant leakage of organic and mineral components from root cells (Welch and Norvell 1993). The effect of different concentrations of Zn on growth, plant metabolism and yield have been discussed in recent reviews by Cakmak *et al.* 1997, Grant and Bailey 1997, Raghuwanshi *et al.* 1997, Wheal and Rengel 1997 and Yilmaz *et al.* 1997).

The effect of mycorrhizal symbiosis on the reaction of plants to toxic levels of heavy metals has been studied with various systems. Dixon and Buschena (1988) showed that ectomycorrhizal colonisation can protect *Pinus banksiana* seedlings from heavy metal toxicity at low or intermediate soil concentrations, Bradley *et al.* (1981) measured an increased heavy metal resistance in ericoid mycorrhizal *Calluna vulgaris* compared with non-inoculated controls. Shetty *et al.* (1994) stated that plants inoculated with mycorrhizal fungi retained more Zn in roots than in shoots which may be considered as a mechanism of Zn tolerance.

Also, the role of vesicular-arbuscular mycorrhiza (VAM) in enhancing plant growth and yield of many field crops has been well documented (Bolan 1991).

The objective of the present investigation was to study the effect of severe heavy metal polluted Nile water and soils and of the presence of vesicular-arbuscular mycorrhizal (VAM) fungi to ameliorate the toxic effect of these metals on plant growth and yield of *Triticum aestivum* and *Vicia faba* in order to evaluate the possibility of growing of these two species in a polluted area.

MATERIAL AND METHODS

Caryopses of wheat (*Triticum aestivum* Giza 164) and seeds of bean (*Vicia faba* Giza 461) were selected for the present study. They were surface-sterilized by soaking in 1% (w/v) sodium hypochloride solution for 5 minutes, then washed thoroughly with distilled water. Twenty caryopses from wheat and ten seeds from bean were sown into individual pots each containing 7 kg of sieved loam soil (clay:sand = 2:1). Soil chemical and physical characteristics were: organic carbon = 0.45%, SO_4^{2-} = 0.015%, Cl^- = 0.078%, HCO_3^- = 0.062%, $CaCO_3$ = 2.6%, K^+ = 0.49 µM/g, Na^+ = 8.4 µM/g, Ca^{2+} = 5.99 µM/g, pH = 7.79, E.C. = 3.55 m.mhos/cm, sand = 26.2%, silt = 30.8%, clay = 43.0%, mean porosity = 40.4%, mean W.H.C. = 61% and mean moisture content = 27.3%.

The group of pots of each plant was divided into three sets, each set contains 7 pots as a replicates. First set were irrigated with natural Nile water to be maintained as controls where its natural content from Zn of about 0.91 ppm (0.14×10^{-4} mM/ml). The plants of second set irrigated with polluted water, where this water was collected from industrial discharge of Talkha manufacture for fertilizers at Besendela bridge far from the source of pollution by about 10 km. At this point, the polluted water will be used for irrigated of about 50 fadan till Gammesa region, the concentration of Zn for about 5.5 ppm (0.84×10^{-4} mM/ml). The third set were irrigated with polluted water after inoculation of soil with vesicular-arbuscular mycorrhizal (VAM) fungi. VAM inoculum was prepared as recommended by Abdel-Fattah (1997).

Irrigation was carried out according to the usual practice by adding equal amounts of water to remain the water holding capacity at 60% where the irrigation in Egypt depends mainly on Nile water. Plants were exposed to normal day length with natural illumination in a greenhouse of Faculty of Science of Mansoura University in winter season. The photoperiod was approximately 10 hours and the day/night temperature was about 20/14 ±2 °C.

Throughout the growth of plants, sampling was carried out at three successive, phenological stages referred to as vegetative (for wheat and bean 32 days after emergence); flowering (for wheat after emergence 83 days and for bean after 56 days) and fruiting (for wheat after 154 days and for bean after 106 days) stages. At the time of sampling, the plants were collected from each pot and separated into shoots and roots for measurement of growth parameters, as well as for chemical analysis. At harvest, carbohydrate, nitrogen and ionic concentrations were determined, in the seeds.

The full data of growth responses of differentially treated set of plants and of the chemical analysis of the harvested seeds were statistically analyzed and comparison among means was carried out by calculating the least significant difference (LSD) at 5% level (Snedecor and Cochran 1969).

Determination of yield and yield attributes

As described by Hassanein (1987), ten plants were taken at random to take the data of yield components which includes the followings:
- Plant height (cm).
- Plant weight (g).
- Crop weight/plant.
- No of grains or seeds/plant.
- Straw weight/plant (g).
- Grains or seeds weight/plant (g).
- Weight of 100 seeds or grains (g).
- Harvest index $\left(\frac{seeds\ weight\ /\ plant(g)}{straw\ weight\ /\ plant(g)} \times 100 \right)$ according to Zelitch (1975).
- Mobilization index $\left(\frac{crop\ weight\ /\ plant(g)}{straw\ weight\ /\ plant(g)} \right)$ according to Ray and Choudhuri (1980).
- Crop index $\left(\frac{seeds\ weight\ /\ plant(g)}{seedsweight\ /\ plant(g) + straw\ weight\ /\ plant(g)} \right)$

Determination of ion contents

For estimation of cations dry samples were digested in concentrated nitric acid and perchloric acid (4:1 v/v) and made up to a fixed volume with deionized water as described by Chapman and Pratt (1978). Flame emission spectrophotometry was used for determining K^+ and Na^+, while Ca^{2+}, Mg^{2+}, Fe^{2+} and Zn^{2+} were measured by atomic absorption spectrophotometry.

Determination of nitrogen

Nitrogenous constituents were extracted from the dry powdered tissues by the method of Yemm and Willis (1956). Ammonia-N and total soluble-N was determined in the extracts and total-N in the dry tissues by the conventional micro-Kjeldahl method. Subtraction of total soluble-N from total-N gave the value for protein-N.

Determination of carbohydrates

Sugars were extracted by overnight submersion in 10 cm^2 80% (v/v) ethanol at 25 °C with periodic shaking. Glucose and sucrose were determined using modifications of the procedures of Feteris (1965) and Handel (1968), respectively.

Estimation of glucose

A 1.0 cm^3 aliquot of the alcoholic extract was heated with 5.0 cm^3 O-toluidine reagent (60 cm^3 o-toluidine and 2.0 g thiourea made to 1.0 dm^3 with glacial acetic acid) for 15 min at 97 °C. Absorbance was measured with a Bausch and Lomb spectronic 20 spectrophotometer at 630 nm.

Estimation of sucrose

Sucrose content was determined by first degrading reactive sugars present in 0.1 ml extract with 0.1 ml 5.4 N KOH at 97 °C for 10 min. Three ml of freshly prepared anthrone reagent (150 mg anthrone +100 ml of 72% H_2SO_4) were then added to the cooled reaction product and the mixture was heated at 97 (for 5 min, cooled and read at 620 nm).

Estimation of polysaccharides

Polysaccharides were determined in dry residue after alcohol extraction as described by Younis *et al.* (1969), its reducing power estimated as mentioned above.

RESULTS AND DISCUSSION

Growth response and yield components

Throughout the experimental period, irrigation with industrial effluents induced a marked changes in the measured growth parameters of *Triticum aestivum* and *Vicia faba* plants. In general, treatment with industrial effluents and in combination with VAM variably enhanced the growth of *Triticum aestivum* (see Table 1). This enhancement was more pronounced in case of treatment with VAM than with industrial effluents alone.

Table 1
Tolerance index of *Triticum aestivum* plant

Phenological stage	Treatment	
	P	P+M
Vegetative	0.96	1.47
Flowering	1.48	1.74
Fruiting	1.63	1.95

Comparing growth of plant root in presence of metal in an industrial effluents with its growth in a control giving the values known as a tolerance index (TI). (TI = root growth in treatment solution/root growth in control solution, Jowett 1958) as shown in Table 1.

TI increase throughout the growth period and magnitude of increase in TI appeared to be high in treatment with industrial effluents in combination with VAM than with industrial effluents alone, this is in accordance with those obtained by Piola *et al.* (1995) whom found that, development of root system was concomitantly accompanied by an enhancement of shoot growth due to effect of ectomycorrhizal fungi of hybrid larch.

Vicia faba plants appeared to be more sensitive to industrial effluents than wheat as it appears from the results given in Table 2. Thus, all growth parameters were, in general, either significantly decreased or non-significantly changed by treatment with industrial effluents and in combination with VAM respectively during vegetative and flowering stages. This result is in accordance with those obtained by El-Hamid *et al.* (1992). Meanwhile a significant increase was in growth parameters obtained during fruiting stage. Tolerance index (TI) in *Vicia faba* plants increased throughout the growth period with treatment of industrial effluents, while a reverse situation was obtained in case of combination with VAM in Table 2.

Yield and yield components

Comparing yield components of wheat and bean plants (Table 3), irrigation with industrial effluents and with VAM appeared to induce changes more or less comparable with those of growth parameters. Grain or seed weight per plant and weight of 100 grains or seeds (seed index) were significantly increased by irrigation with industrial effluents. The same pattern was recorded in mobilization index, harvest index and crop index. Thus, in wheat plants irrigated in combination with VAM, grain weight/plant was non-significantly affected by these effluents, but num-

Table 2
Tolerance index of *Vicia faba* plant

Phenological stage	Treatment	
	P	P+M
Vegetative	0.85	1.00
Flowering	0.90	0.98
Fruiting	1.13	0.97

ber of grains/plant, mobilization index, harvest index and crop index were significantly decreased. For bean plants, number of seed/plants was significantly decreased.

It is apparent from the results in Table 4 that, there was a significant positive correlation between grain weight/plant and other yield attributes in wheat plant. For bean seeds, the same behaviour was obtained except a negative correlation was recorded between the number of seeds/plant and other yield attributes as clear in Table 5. In this connection, Raghuwanshi *et al.* (1997) using wheat plants, they found that, the application of Zn as 5 kg $ZnSO_4$/h and 5, 10 kg $ZnCl_2$/h gave higher yield. Furthermore Yilmaz *et al.* (1997) found that application of Zn at 0.12 mg $kg^{(-1)}$ significantly increased grain yield in all cultivars of wheat. These results were in accordance with those obtained by Modaihash (1997) and Cakmak *et al.* (1996) on wheat.

Table 3
Dry weight of roots, shoots and leaves; length and leaf area of *Triticum aestivum* in three phenological phases as affected by type of irrigation water

Treatment	Phenological stage	Root	Stem (mg)	Leaves	Root	Stem (cm)	Leaf area (cm^2)
Control	1	9	20*	20	4.2*	5.9	5.9
Polluted		10	20*	10	4.0*	4.6	4.5
Polluted + VAM		7	8	7	6.1	4.1	3.6
L.S.D. at 0.05		1.1	2.03	1.5	0.57	1.11	1.5
Control	2	60	410	50	9.3	38.6	11.4
Polluted		120	700	70	13.8	42.2	14.6
Polluted + VAM		270	630	80	16.2	30.1	14.8
L.S.D. at 0.05		8.7	11.5	3.47	1.11	1.25	1.31
Control	3	70	460	40	15.00	53.6*	14.3
Polluted		150	790	70	15.5	62.4	16.3
Polluted + VAM		330	720	60	18.6	54.6*	17.1
L.S.D. at 0.05		9.3	12.8	1.5	0.15	2.35	1.82

* Non significant as indicated L.S.D. ($P \leq 0.05$)

Table 4

Dry weight of roots, shoots and leaves; length and leaf area of *Vicia faba* in three phenological phases as affected by type of irrigation water

Treatment	Phenological stage	Root	Stem (mg)	Leaves	Root	Stem (cm)	Leaf area (cm^2)
Control	1	70	130	70*	6.0*	16.6	21.6
Polluted		60	200	70*	5.1	15.4	24.3
Polluted + VAM		130	280	110	6.0*	14.2	38.6
L.S.D. at 0.05		8.7	10.3	4.3	0.31	0.15	1.08
Control	2	270	113	130	10.1*	36.8*	39.7*
Polluted		280	820	90	9.1	39.7	30.4
Polluted + VAM		340	980	190	10.0*	37.1*	39.7*
L.S.D. at 0.05		9.1	11.5	15.8	0.13	0.35	0.15
Control	3	740	231	210	12.3*	67.0	48.2
Polluted		102	260	270	14.0	74.0	51.7
Polluted + VAM		196	240	220	12.0*	71.1	49.3
L.S.D. at 0.05		15.8	5.4	7.3	0.41	0.73	0.25

* Non significant as indicated L.S.D. ($P \leq 0.05$)

Table 5

Effect of industrial effluents (P = polluted) and mycorrhiza (P+VAM) on different yield attributes of *Triticum aestivum* and *Vicia faba*. (C = control, pl = plant). Each value is the mean of 5 replicates

	Treatment							
	Triticum aestivum				*Vicia faba*			
Parameter	C	P	P+VAM	L.S.D. at 0.05	C	P	P+VAM	L.S.D. at 0.05
Plant height (cm)	58.6	67.4	59.6	0.51	70.0	88.0	75.1	2.88
Plant weight (g)	1.1*	1.6	1.2*	0.15	60.1	73.5	58.2	1.95
Crop weight (g)	0.7*	1.0	0.7*	0.05	12.7	20.4	14.4	0.85
No. of grain/plant	12.0	18.0	11.0	0.43	4.0	3.0	3.0	0.31
Straw wt./pl/(g)	0.4	0.6	0.5	0.03	2.5*	2.8	2.6*	0.15
Grain wt./pl/(g)	0.6*	0.9	0.6*	0.01	2.0	5.0	3.6	0.45
Wt. 100 grains (g)	4.7*	5.6	4.7*	0.03	50.0	166.2	120.0	4.7
Mobilization index	1.5	1.6	1.4	0.08	5.0*	7.2	5.5*	0.65
Harvest index	128.4	136.7	118.6	2.1	77.9	176.1	136.8	8.75
Crop index	0.6*	0.6*	0.5	0.04	0.4	0.6	0.6	0.11

* Non significant as indicated L.S.D. ($P \leq 0.05$)

Changes in carbohydrates

Results presented in Figures 1–2 show, that irrigation of wheat and bean plants with industrial effluents either alone or with VAM leads to increase in total soluble in both shoots and roots. For sucrose in wheat except in shoots of industrial effluents, there were a significant decrease in its amount in both shoots and roots. Polysaccharides and total carbohydrates were significantly decreased with irrigation by industrial effluents and increase with VAM in shoots and roots. In bean plants, sucrose, polysaccharides and total carbohydrates were significantly decrease in shoot with industrial effluents and increased with VAM. Generally, in root, there was a significant increase in sucrose, polysaccharides, and total carbohydrates. These results were in accordance with those obtained by Abbas and Shukry (1993) and Abbas (1986) on *Zea mays*. It is well-known now, that Zn plays an important role in carbohydrate metabolism (Vallee 1976) and the increase in soluble sugars in presence of Zn demonstrates the increase in the activities of enzymes responsible for sugar synthesis in maize (Powell *et al.* 1986).

Bjorkman (1942) suggested that host would allocate less carbohydrate to the mycobiont at high levels of nitrogen and phosphorus, availability owing to a greater demand for carbon by growing shoots under such conditions where the amount of ammonia-N and phosphorus in industrial wastewater were 0.166 mg/l and 0.077 mg/l, respectively where in control they were 0.009 mg/l and 0.022 mg/l. On the other hand, Wallander and Nylund (1991) found, that carbohydrate pool in roots increased in response to elevated N levels; still, mycorrhizal development was reduced.

Changes in nitrogen metabolism

Results presented in Figures 3–4 clearly indicate that the irrigation with industrial effluents and with VAM favoured an increase in ammonia-N, total soluble-nitrogen, protein-N. The net result is the increased total nitrogen that was attenuated at irrigation with industrial effluents with VAM. These results are in accordance with those obtained by Abbas (1986) and Powell *et al.* (1986). A significant increase in ammonia-N, total soluble-N in shoot and root was obtained during the growth of bean plants, however protein-N and total-N were decreased in response to irrigation with industrial effluents and with VAM, where Wallander (1995) found, that carbohydrates of the host allocated to the mycorrhizal fungus are used in growth processes and as carbon skeleton and energy sources in the process of ammonium assimilation. The assimilated N is either used in growth processes by the fungus, stored as amino acids or protein in the fungal mantle or returned to the host in the form of amino acids. A number of studies have shown that the formation of ectomycorrhizae alters the char-

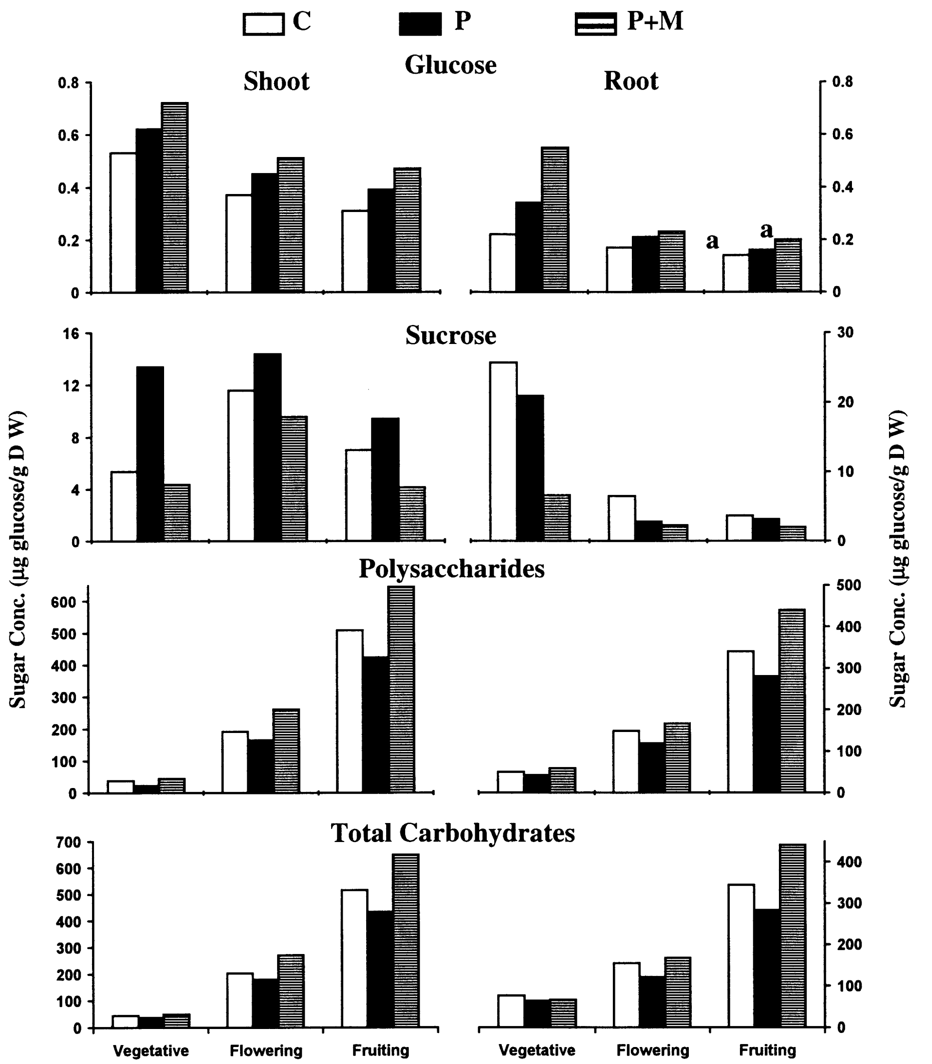

Fig. 1. Effect of irrigation with Nile water (control), industrial effluents (P) and VAM (P+M) on carbohydrate concentration in *Triticum aestivum* plants at three development stages. The bars with the same letter are not significantly different at p-level = 5% (LSD) test

acteristics of nitrogen acquisition and assimilation depending on the fungus and host plant species (Chalot *et al.* 1994).

Biochemical composition of seeds

Carbohydrate content. In the harvested wheat grains and bean seeds, there was a significant decrease in reducing sugars and sucrose with an in-

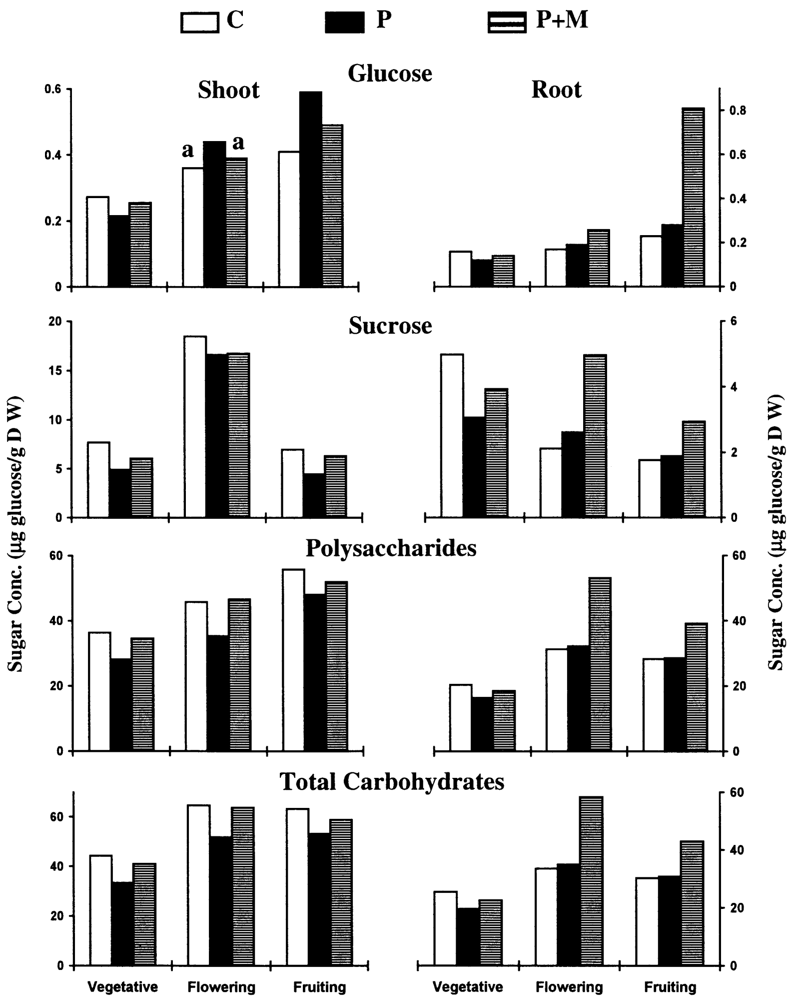

Fig. 2. Effect of irrigation with Nile water (control), industrial effluents (P) and VAM (P+M) on carbohydrate concentration in *Vicia faba* plants at three development stages. The bars with the same letter are not significantly different at p-level = 5% (LSD) test

crease in polysaccharides and total carbohydrates, in response to industrial effluents and with VAM. This may be due to the enhanced effect of industrial wastewater on synthesis and accumulation of carbohydrates. On the other hand the reserve losses from shoot (Figs 3–4) were gained by

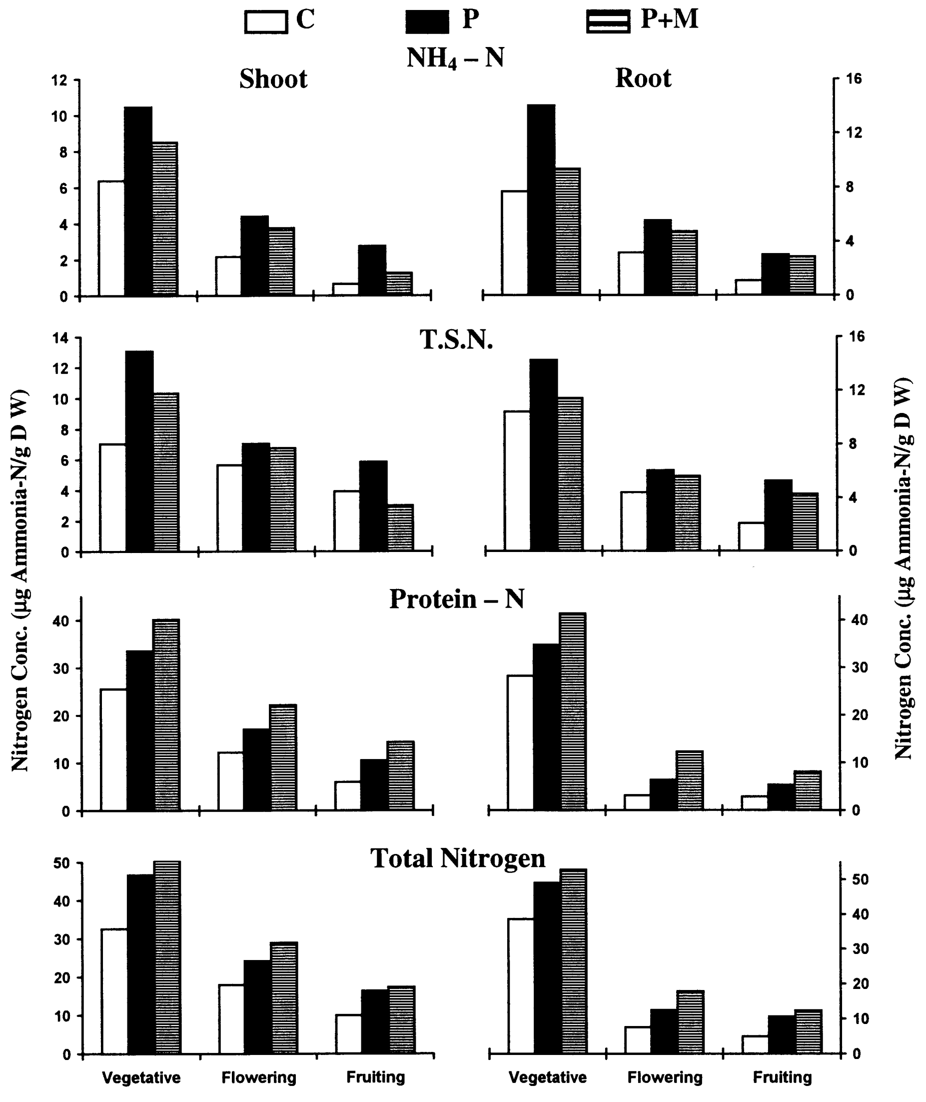

Fig. 3. Effect of irrigation with Nile water (control), industrial effluents (P) and VAM (P+M) on nitrogen concentration in *Triticum aestivum* plants at three development stages. The bars with the same letter are not significantly different at p-level = 5% (LSD) test

grains of wheat or seeds of bean as shown in Table 6, most of which appeared to come from translocation of current assimilate, where Zn play an important role in carbohydrate metabolism (Abbas 1986, Powell *et al.* 1986 and Vallee 1976).

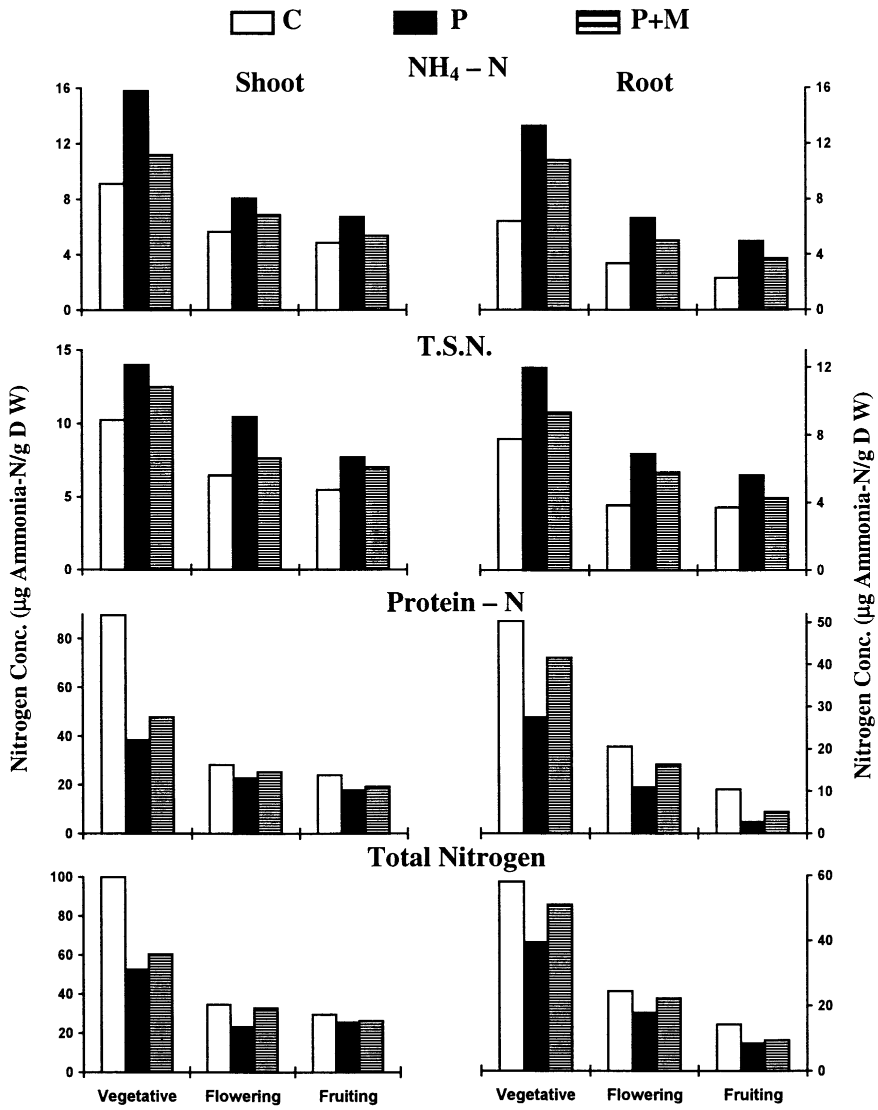

Fig. 4. Effect of irrigation with Nile water (control), industrial effluents (P) and VAM (P+M) on nitrogen concentration in *Vicia faba* plants at three development stages. The bars with the same letter are not significantly different at p-level = 5% (LSD) test

Table 6
Simple correlation coefficiens between different yield attributes in *Triticum aestivum*. Significance (p-level) **=1%, *= 5%

Parameter	Height (cm)	Weight (g)	Crop wt (g)	No. of grain/pl.	Straw wt./pl./G.	Grain wt./pl./G	Wt 100 grains (g)	Mobiliza-tion index	Harvest index	Crop index
Plant height (cm)	1.000									
Plant weight (g)	0.996**	1.000								
Crop weight (g)	0.999**	0.994**	1.000							
No. of grain/plant	0.972**	0.949**	0.978**	1.000						
Straw wt./P/(g)	0.961**	0.981**	0.954**	0.871**	1.000					
Grain wt./P/(g)	0.998**	0.996**	0.997**	0.964**	0.966**	1.000				
Wt 100 grains (g)	0.109	0.025	0.134	0.338	–0.167	0.089	1.000			
Mobilization index	0.493*	0.418*	0.515*	0.683**	0.235	0.472*	0.918**	1.000		
Harvest index	0.777**	0.722**	0.793**	0.903**	0.575*	0.761**	0.709**	0.930**	1.000	
Crop index	0.754**	0.697**	0.770**	0.884**	0.547*	0.734**	0.722**	0.934**	0.993**	1.000

Table 7
Simple correlation coefficients between yield attributes and other measured parameters in *Vicia faba*. Significance (p-level) **=1%, *= 5%

Parameter	Height (cm)	Weight (g)	Crop wt (g)	No. of grain/pl.	Straw wt./pl./G.	Grain wt./pl./G	Wt 100 grains (g)	Mobiliza-tion index	Harvest index	Crop index
Plant height (cm)	1.000									
Plant weight (g)	0.987**	1.000								
Crop weight (g)	0.987**	0.948**	1.000							
No. of grain/plant	–0.547**	–0.403**	–0.673**	1.000						
Straw wt./P/(g)	0.961**	0.904**	0.993**	–0.756**	1.000					
Grain wt./P/(g)	0.871**	0.780**	0.938**	–0.887**	0.973**	1.000				
Wt 100 seeds (g)	0.930**	0.858**	0.977**	–0.816**	0.995**	0.991**	1.000			
Mobilization index	0.990**	0.953**	1.000**	–0.661**	0.991**	0.933**	0.973**	1.000		
Harvest index	0.834**	0.733**	0.911**	–0.918**	0.954**	0.998**	0.978**	0.905**	1.000	
Crop index	0.766**	0.652**	0.859**	–0.957**	0.914	0.983**	0.949**	0.851**	0.994**	1.000

Table 8
Effect of industrial effluents and mycorrhiza (Polluted + VAM) on chemical composition in grains of *Triticum aestivum* and seeds of *Vicia faba*

	Treatment							
	Triticum aestivum				*Vicia faba*			
Parameter	Control	Polluted	Polluted + VAM	L.S.D. at 0.05	Control	Polluted	Polluted + VAM	L.S.D. at 0.05
Carbohydrates (mg glucose/g DW)								
Glucose	0.045	0.020	0.031	0.001	0.182	0.052	0.106	0.02
Sucrose	1.540	0.533	0.720	0.05	5.762	1.374	3.364	0.15
Polysaccharides	703.95	715.04	790.32	7.33	391.810	190.990	229.590	8.35
Total carbohydrates	705.53	715.59	791.07	6.15	397.760	192.420	233.060	13.9
Nitrogen (mg NH_4-N/g DW)								
Ammonia-N	0.430	0.950	0.790	0.25	4.460	6.130	5.110	0.38
Total soluble-N	2.660	4.140	3.110	0.53	25.63	27.62	26.11	0.11
Protein-N	116.00	110.500	128.370	3.5	30.820	27.760	31.890	0.15
Total-N	118.66	114.64	131.48	2.7	56.45	55.35	58.00	0.43
Elements (m mole/g DW)								
Potassium m mole g^{-1}	32.5	25.9	29.3	3.8	0.1	0.06	0.06	0.005
Sodium m mole g^{-1}	6.0*	16.2	7.8*	1.9	0.15	0.03	0.03	0.002
Calcium m mole g^{-1}	2.2*	1.2	2.0*	0.31	0.05	0.02	0.02	0.001
Magnesium µ mole g^{-1}	11.9*	9.1*	16.4	3.1	37.2	9.9	12.7	2.31
Iron µ mole g^{-1}	0.3	0.04	0.2	0.05	2.9	1.4	0.15	0.53
Zinc µ mole g^{-1}	1.5*	4.5	1.8*	0.53	17.9	0.8	10.54	1.45

Nitrogen content. The pattern of changes in nitrogen constituents is shown in Table 4. The observed general decrease in protein-N is accompanied with an increase in total soluble-N in wheat grain in response to industrial effluents this may be attributed to the promotive effects on the proteolytic activity. On the other hand, there was a significant increase in protein-N in response to VAM whereas a reverse situation was obtained in bean seeds.

Mineral content. Data presented in Table 6 indicate, that K, Ca, Mg and Fe contents were significantly decreased in wheat grains with irrigation by industrial effluents and in combination with VAM except Mg ions that were significantly increase with VAM.

Concerning the contents of Na and Zn ions in wheat grain, they were significantly increased with industrial effluents or non-significant change with VAM.

Regarding the effect of irrigation with industrial effluents on ion content of bean seeds, the results revealed that all tested elements (K, Na, Ca, Mg, Fe and Zn) were significantly decreased in both treatments. In accordance with these results Wolswinkel (1992) emphasised that most nutrient enter the developing fruit via the phloem. Indeed much work has been reported on the pathway by which carbohydrates and macronutrients enter the developing fruit (Wolswinkel 1987, 1992).

The pathway used by micronutrients to enter into developing seeds has generally been assumed to be similar to that of macronutrients, that is transport via the phloem (Longnecker and Robson 1993), Zn ions are thought to be only partially mobile in the phloem (Kochian 1991) and are remobilised from leaves during grain or seed development (Pearson and Rengel 1994), where it mobilised in the phloem as organic complexes with citrate or malate (Longnecker and Robson 1993).

For the final conclusion, it seems that wheat and bean plant subjected to irrigation with industrial wastewater, increased in growth criteria throughout the growth of plant and the presence of inoculum from VAM may lead either to a significant increase in growth (in bean) or non-significant change (in wheat). The tolerance index in wheat was higher than that in bean.

This was accompanied with an increase in total carbohydrates and total nitrogen in shoots and roots of wheat plants. On the other hand, total carbohydrates and total nitrogen in bean plants were significantly decreased in polluted soil or did not significantly change in combination with VAM. This means that we can use industrial effluents for irrigation, with regarding that bean plants were more sensitive to polluted water, while wheat plants were less or moderately sensitive to heavy metals in polluted water. On the other hand, the presence of VAM may enhance the growth and increase the tolerance to these heavy metals in beans.

The number of grains/plant and the weight of 100 caryopses significantly increased in wheat and in bean in response to irrigation with industrial effluents, *i.e.* the quality of grains or seeds were significantly increase. However, the quantity of carbohydrates in wheat were increased although the nitrogen content was decreased and increased in response to polluted water and with VAM, respectively. For beans total carbohydrates were decreased. Although total-N was significantly decrease with polluted water and increased with VAM.

The ionic content of grains revealed that wheat grain contained a high amount of Zn in response to irrigation with industrial effluents, but in beans, the decrease in Zn content was attenuated, *i.e.* wheat grains contain high amount from carbohydrates and Zn, but low in protein, and a reverse situation in bean plants. These lead us to consider that wheat plants (as monocot) can tolerate these pollutants, where (1) Zn deficiency is a critical nutritional problem in Egypt substantially limiting wheat production; (2) high level of Zn in grains of wheat may help in solving the problem of widespread occurrence of Zn deficiency in children in Egypt, whose diets are dominated by cereals-based food with a low protein content. These are in case of irrigation with industrial effluents alone. On the other hand, bean (dicot) which is more sensitive to industrial effluents, can be grown and irrigated with industrial effluents but in combination with VAM.

REFERENCES

Abbas, M. A. (1986): Effect of Zn on growth and ion relations in Zea mays. – *Mans. Sci. Bull.* **13**: 73–86.

Abbas, M. A. and Shukry, W. M. (1993): Effect of Zn and Fe uptake and some metabolic aspects in maize seedlings. – *Mans. Sci. Bull.* **20**: 57–69.

Abdel-Fattah, G. M. (1997): Functional activity of VA-mycorrhizal fungus (Glomus mosseae) in the growth and productivity of soybean plant grown in sterilized soil. – *Folia Microbiol.* **5**: 495–502.

Abdel-Hamid, I. M., Dessouki, S. S. and Skulberg, O. M. (1993): Water quality of River Nile. III. Toxicity assessments of six industrial effluents polluting the River Nile. – *Environmental Toxicology and Water Quality* **8**: 239–254.

Bjorkman, E. (1942): Über die bedigungen der Mykorrhizabildung bei Kiefer und Fichte. – *Symb. Bot. Ups.* **6**: 2.

Bolan, N. S. (1991): A critical review on the role of mycorrhizal fungi in the uptake of phosphorus by plants. – *Plant and Soil* **134**: 189–207.

Bradley, R., Burt, A. J. and Read, D. J. (1981): Mycorrhizal infection and resistance to heavy metal toxicity in Calluna vulgaris. – *Nature* **292**: 335–337.

Cakmak, I., Ozturk, L., Eker, S., Torun, B., Kalfa, H. I. and Yilmaz, A. (1997): Concentration of Zn and activity of copper/zinc-superoxide dismutase in leaves of rye and wheat cultivars differing in sensitivity to zinc deficiency. – *Journal of Plant Physiology* **151**: 91–95.

Cakmak, I., Yilmaz, A., Kalayci, M., Ekiz, H., Torun, B., Erenoglu, B. and Braun, H. J. (1996): Zinc deficiency as a critical problem in wheat production in Central Anatolia. – *Plant and Soil*. **180**: 165–172.

Chalot, M., Brun, A., Finlay, R. D. and Soderstrom, B. (1994): Metabolism of [^{14}C] glutamine by ectomycorrhizal fungus Paxillus involutus. – *Microbiology* **140**: 1641–1649.

Chapman, H. D. and Pratt, P. F. (1978): *Methods of analysis for soils, plant and waters.* – University of California, Division Agriculture Sci. Priced Publication 4034 pp. 50 and 169.

Dixon, R. K. and Buschena, C. A. (1988): Response of ectomycorrhizal Pinus banksiana and Picea glauca to heavy metals in soil. – *Plant and Soil* **105**: 265–271.

El-Hamid, Kh. H., Taha, A. A. and Abdel Nabi, A. O. (1992): Zinc, iron and manganese fertilization of Pepper plants grown on calcareous soil. – *J. Agric. Sci. Mans. Univ.* **17**: 3687–3692.

Feteris, A. W. (1965): A serum glucose method without protein precipitation. – *American Journal of Medical Technology* **31**: 17–21.

Grant, C. A. and Bailey, L. D. (1997): Effects of phosphorus and zinc fertilizer management on cadmium accumulation in flax seed. – *Journal of the science of food and agriculture* **73**: 307–314.

Handel, E. V. (1968): Direct microdetermination of sucrose. – *Analytical Biochemistry* **22**: 280–283.

Hassanein, M. S. (1987): *Effect of some micro-nutrients on soybean.* – M. Sc. Thesis, Fac. Agric., Moshtohor, Zagazig Univ., Zagazig, Egypt.

Jowett, D. (1958): *Nature* **182**: 816–817.

Kochian, L. V. (1991): Mechanisms of micronutrient uptake and translocation in plants. – In: Morted, J. J., Cox, F. R., Shaurman, C. M. and Welch, R. M. (eds): Micronutrients in Agriculture, 2nd Ed. Soil Science Society of America, Madison, WI, pp. 297–328.

Longnecker, N. E. and Robson, A. D. (1993): Distribution and transport of zinc in plants. – In: Robson, A. D. (ed.): Zinc in soils and plants. Kluwer Academic Publishers, Dordrecht, pp. 79–91.

Modaihash, A. S. (1997): Foliar application of chelated and non-chelated materials for supplying micronutrients to wheat grown on calcareous soil. – *Experimental Agriculture* **33**: 237–245.

Pearson, J. N. and Rengel, Z. (1994): Distribution and remobilization of Zn and Mn during grain development in wheat. – *J. Exp. Bot.* **45**: 1829–1835.

Piola, F., Rohr, R. and Von Aderkas, P. (1995): Controlled mycorrhizal initiation as a means to improve root development in somatic embryo plantlets of hyprid larch (Larix eurolepis). – *Physiologia Plantarium* **95**: 575–580.

Powell, M. J., Davies, M. S. and Francis, D. (1986): Effects of zinc on cell, nuclear size, and on RNA and protein content in the root meristem of zinc-tolerant and a non-tolerant cultivar of Festuca rubra L. – *New Phytol.* **104**: 671–679.

Powell, M. J., Davies, M. S. and Francis, D. (1988): Effects of zinc on meristem size and proximity of root hairs and xylem elements to root tip in a zinc-tolerant and a non-tolerant cultivar of Festuca rubra L. – *Ann. Bot.* **61**: 723–726.

Raghuwanshi, R. K. S., Sinha, N. K. and Agrawal, S. K. (1997): Effect of sulphur and zinc in soybean (Glycine max)-wheat (*Triticum aestivum*) cropping sequence. – *Indian Journal of Agronomy* **42**: 29–32.

Ray, S. and Chaudhuri, M. A. (1980): Regulation of flag leaf senescence in rice by nutrients and its impact on yield. II. – *Riso* **29**: 9–14.

Rosen, J. A., Pike, C. S. and Golden, M. L. (1977): Zn, Fe and chlorophyll metabolism in zinc-toxic corn. – *Plant Physiol.* **59**: 1085–1087.

Shetty, K. G., Hetrick, B. A. D. Figge, D. A. H. and Schwab, A. P. (1994): Effects of mycorrhizal and other soil microbes on revegetation of heavy metal contaminated mine spoil. – *Environ. Pollution* **86**: 181–188.

Snedecore, C. W. and Cochran, W. G. (1967): *Statistical methods.* – 6th edition. Oxford and IBH Publishing Co. New Delhi.

Vallee, B. L. (1976): Zinc biochemistry: A prospective. – *Trends Biochem. Hort. Sci.* **71**: 496–506.

Wallander, H. (1995): A new hypothesis to explain allocation of dry matter between mycorrhizal fungi and pine seedling in relation to nutrient supply. – *Plant and Soil*: 168–169.

Wallander, H. and Nylund, J. E. (1991): Effects of excess nitrogen on carbohydrate concentration and mycorrhizal development of Pinus sylvestris L. seedlings. – *New Phytol.* **119**: 405–411.

Welch, R. M. and Norvell, W. A. (1993): Growth and nutrients uptake by barley (Hordeum vulgara L. cv. Herta): Studies using an N-(2-hydroxyethyl) ethylene dinitrilotriacetic acid-buffered nutrient solution technique. II. Role of zinc in the uptake and root leakage of mineral nutrients. – *Plant Physiol.* **101**: 627–631.

Wheal, M. and Rengel, Z. (1997): Chlorsulfuron reduces rates of zinc uptake by wheat seedlings from solution culture. – *Plant and Soil* **188**: 309–317.

Wolswinkel, P. (1987): Assimilate transport into developing seeds of sunflower (Helianthus annuus L.). – *J. Plant Physiol.* **127**: 1–10.

Wolswinkel, P. (1992): Transport of nutrients into developing seeds: a review of physiological mechanisms. – *Seed Sci. Res.* **2**: 59–73.

Yemm, E. W. and Willis, A. J. (1956): The respiration of barley plants. IX. The metabolism of roots during the assimilation of nitrogen. – *New Physiologist* **55**: 229–252.

Yilmaz, A., Ekiz, H., Torun, B., Gultekin, I., Karanlik, S., Bagci, S. A. and Cakmak, I. (1997): Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc-deficient calcareous soils. – *Journal of plant nutrition* **20**: 461–471.

Younis, A. E., Younis, M. E. and Gabr, M. A. (1969): Studies on the effect of certain enzymatic poisons on the metabolism of storage organs. II. Differential effects of iodoacetate on the respiratory metabolism and permeability barriers of radish root slices. – *Plant and Cell Physiology*.

Zelitch, I. (1975): Improving the efficiency of photosynthesis. – *Science* **188**: 626–633.