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IRON NUTRITION OF SIX CULTIVARS OF SUNFLOWER[1]

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ABSTRACT

Six high-oil cultivars of sunflower (*Helianthus annuus* L.) were grown in nutrient solution with an initial pH of 5 containing no Fe or 2 ppm Fe either in the form of inorganic Fe^{3+} or FeEDDHA in order to study their efficiency of utilizing Fe compounds.

An initial Fe chlorosis was observed for all cultivars in solution without Fe by the time the pH of nutrient solution was declining. However, plants in medium containing inorganic Fe^{3+} or FeEDDHA increased the pH with time without development of chlorosis. It was proposed that with inorganic Fe^{3+} supply, Fe requirement of plant was satisfied due to direct contact of Fe^{3+} phosphate particles with the root surface.

Growth response of the six cultivars to inorganic Fe^{3+} or to FeEDDHA was somewhat similar. However, the Fe concentration in the shoot of all cultivars was significantly higher with FeEDDHA than inorganic Fe^{3+}, which indicated a better availability of Fe from FeEDDHA. The Fe concentration of the shoots caused a significant difference in P: Fe ratio.

It was concluded that cultivation of sunflower cultivars used in this experiment has no limitation in respect to utilization of Fe compounds, even in the form of inorganic Fe.

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INTRODUCTION

Plant species, varieties and inbred line differ in their ability for utilizing Fe from growth media (1, 10, 15). On the basis of this, plants have been arbitarily classified as Fe-efficient and Fe-inefficient. Fe-efficient plants under Fe stress condition have mechanisms that bring about some metabolic changes in the plant that alter the root environment and favor the absorption and translocation of Fe. Changes in the pH of the growth medium, release of reducing substances (4, 5, 6, 7), production of riboflavin (17, 19, 22), differential uptake of anions and cations (18, 21), citrate accumulation in the root (7, 8, 19), Fe and phosphate accumulation and their translocation in the plants (3, 11, 14) are the factors generally studies to determine the ability of plants to utilize Fe under Fe stress conditions.

The purpose of the present study was to evaluate the responses of six newly introduced cultivars of sunflower (*Helianthus annuus* L.) to inorganic and organic Fe sources.

MATERIALS AND METHODS

Seeds of six high-oil yielding sunflower cultivars (Louck, Peredovik, Orizont, Zarea, Record and Mhjak) were germinated in vermiculite and after 10 days, transferred on a ring to 3.2-liter jars in the greenhouse. Each jar contained four plants in 3 liters of nutrient solution with the following composition in mM/liter: $Ca(NO_3)_2$, 3.75; KH_2PO_4, 0.75 and $MgSO_4$, 0.75. The concentration of micronutrients was 1 ppm for B and Mn and 0.1 ppm each for Zn, Cu and Mo. The nutrient solution received either no Fe or 2 ppm Fe as $FeCl_3$ or FeEDDHA (Sequestrene 138 Fe). The design of the experiment was a randomized complete block, arranged in factorial manner. The experiment was replicated three times.

The initial pH of the nutrient solution was adjusted to 5.0 and the pH was measured daily during the course of the experiment. The nutrient solution was continually aerated and water loss was compensated for by addition of distilled water. After 15 days, plants were harvested and the roots were washed with distilled water and separated from the shoots. Shoots and roots were sampled separately, dried at 70C, weighed, ground and digested in a nitric, perchloric and sulfuric acid mixture (in proportion of 75 : 30 : 15 ml, respectively). Phosphorus was determined by vanadomolybdophosphoric yellow method (12), and Fe by Carl Zeiss Atomic Absorption Spectrophotometer. Data were subjected to the analysis of variance and means were compared using Duncan's new multiple range test.

RESULTS AND DISCUSSION

In the course of experiment, plants which received Fe remained green, while those grown without Fe developed chlorosis after four to five days of growth and remained chlorotic thereafter. Figure 1 shows the changes that occurred in nutrient solutions during 15 days of plant growth.

Plants grown in nutrient solution without Fe developed chlorosis by the time the pH was declining, while in the medium containing inorganic Fe^{3+} or FeEDDHA, the pH was increased and plant did not develop chlorosis. The increase in the pH of the nutrient solution with inorganic Fe^{3+} was either similar or less as compared to the solution with FeEDDHA (Fig. 1). Since no chlorosis was noted for plants supplied with the inorganic Fe^{3+} or FeEDDHA, both could be considered as available forms of Fe for the cultivars of sunflower used. These results are not in agreement with an earlier report (15) where chlorosis was noted whenever plants were supplied with inorganic Fe^{3+}.

Inorganic Fe^{3+} is supposed to be precipitated as Fe^{3+}-hydroxide under similar pH conditions as used in this experiment and in an aqueous solution in the presence of phosphate, it precipitate as Fe^{3+} -phosphate causing plants to suffer from Fe stress (15). In the present study plants did not suffer from Fe shortage due to the fact that sunflower seedlings neither showed any sign of chlorosis nor any lowering of pH in solution containing Fe was noted. It is possible that Fe requirement of plant was satisfied due to direct contact of Fe-phosphate particles with root surface (2, 13).

In all six cultivars tested, dry weight of roots and shoots increased considerably due to FeEDDHA and Fe^{3+} as compared to control plants (Table 1). In cultivar Orizont, a better shoot growth, and in cultivar Mhjak, a better root growth was obtained with FeEDDHA than with inorganic F^{3+}

Iron treatments had pronounced influence of the Fe concentration of root and shoot (Table 1), while the Fe concentration in control plants was considerably lower. In cultivars Zarea, Record and Mhjak the Fe concentration of root was relatively higher with inorganic Fe^{3+} than when FeEDDHA was supplied. This could be due to the precipitation of Fe^{3+} -phosphate on the root surface. The Fe concentration in the shoot of all cultivars was significantly higher with FeEDDHA than with inorganic Fe^{3+} indicating better availability and solubility of Fe from FeEDDHA 9Table 1).

Phosphorus accumulation in plant is another factor that influences susceptibility or resistance of plant to Fe chlorosis (7, 15, 20) due to external (9, 16) and internal inactivation of Fe within the plant (3, 11, 14). Dekock (11) proposed the use of P:Fe ratio as an index of Fe status of plants. Kashirad and Marschner (15) reported that in corn susceptibioity to Fe chlorosis was related to the P:Fe ratio in the shoot rather than to Fe absorption and translocation capacity of plant. Odurukwe and Maynard (18) suggested that with an increase in the relative P concentration of the tissue, more Fe is tied up in phosphate combination and consequently less Fe is available for physiological reaction in the plant.

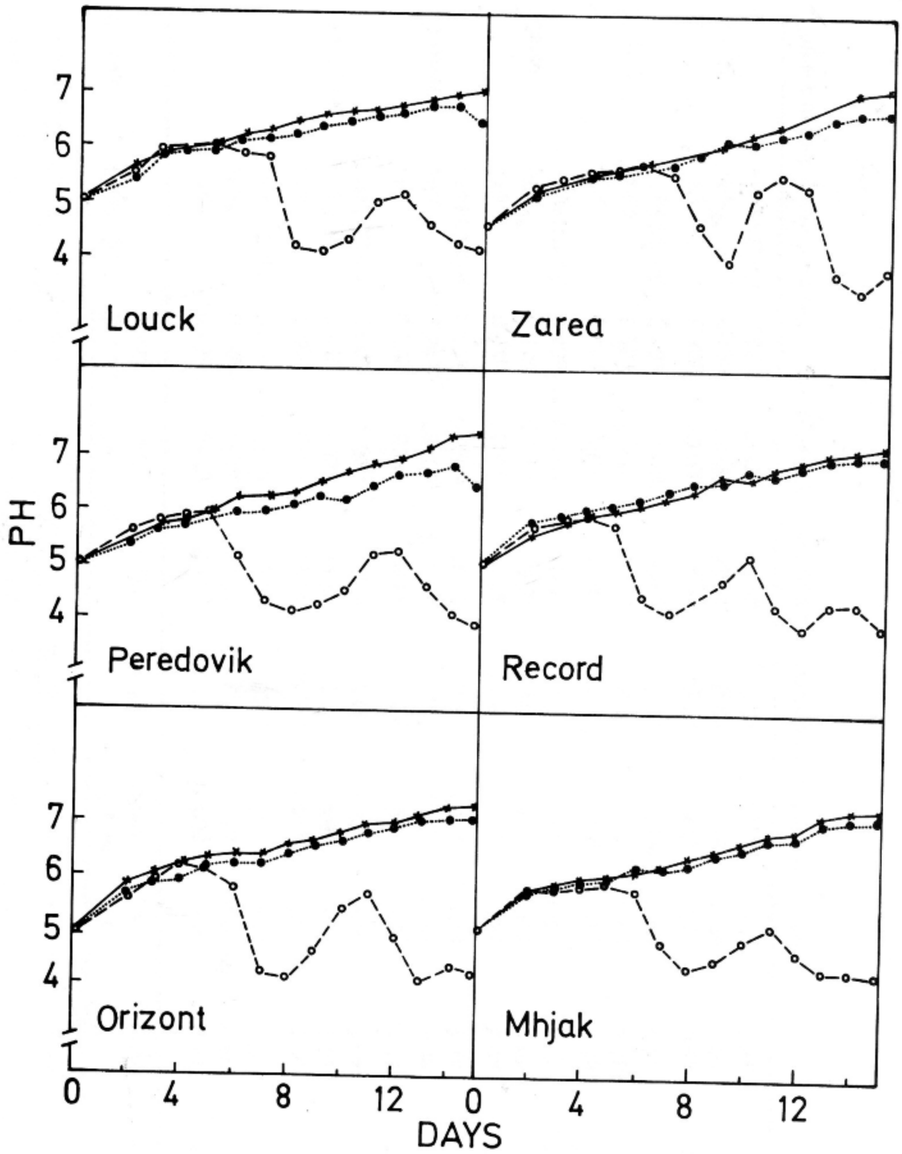

Fig. 1. Changes of the pH of the nutrient solution as affected by sunflower cultivars grown for 15 days in solutions without iron (o —— o—— o —— o) or 2 ppm iron as inorganic Fe^{3+} (• —— • ——•) or FeEDDHA (x—— x —— x).

Table 1. Dry weight, Fe and P concentrations and P/Fe ratio of six cultivars of sunflowers grown for 15 days in nutrient solution without Fe and 2 ppm Fe as inorganic Fe^{3+} and FeEDDHA.

		ROOT				SHOOT			
Cultivar	Treatment	Dry wt. g/pot	Fe ppm	P mg/g	P/Fe	Dry wt. g/pot	Fe ppm	P mg/g	P/Fe
	−Fe	0.45b*	887b	10.6a	12.1a	1.03b	67c	8.5a	126.8a
Louck	$+Fe^{3+}$	0.48ab	1259a	10.2a	8.1b	1.24a	81b	8.4a	103.3b
	+FeEDDHA	0.50a	1243a	10.5a	8.6b	1.25a	89a	7.2b	80.7c
	−Fe	0.49b	514b	12.2a	24.5a	1.31b	70c	7.2a	102.2a
Peredovik	$+Fe^{3+}$	0.48b	1133a	11.4a	10.1b	1.46a	88b	7.2a	83.3b
	+FeEDDHA	0.54a	1269a	8.2b	6.6c	1.53a	102a	7.4a	72.4c
	−Fe	0.50b	638b	10.5a	1.6a	1.29c	95c	9.7a	102.4a
Orizont	$+Fe^{3+}$	0.54ab	1840a	9.6a	5.2b	1.50b	110b	7.6b	70.0b
	+FeEDDHA	0.57a	1691a	10.1a	6.5b	1.70a	127a	7.1c	65.0c
	−Fe	0.43b	830c	8.8b	10.8a	1.38b	76c	8.8a	117.0a
Zarea	$+Fe^{3+}$	0.44b	2049a	9.9a	4.8b	1.54a	120b	7.0b	61.1b
	+FeEDDHA	0.49a	1751b	10.1a	5.8b	1.56a	168a	6.7b	40.2c
	−Fe	0.46a	860c	10.4a	12.3a	1.32b	89c	8.4a	95.8a
Record	$+Fe3^{+}$	0.46a	2354a	10.5a	5.7b	1.44a	127b	7.9b	64.0b
	+FeEDDHA	0.50a	1184b	10.8a	6.1b	1.41ab	148a	6.9c	47.0c
	−Fe	0.48b	1016c	9.7b	9.7a	1.49b	89c	9.6a	101.2a
Mhjak	$+Fe^{3+}$	0.49b	1703a	10.1b	6.0b	1.84a	113b	7.6b	67.7b
	+FeEDDHA	0.55a	1243b	11.4a	9.2a	1.81a	147a	7.4b	51.1c

*Means in each group followed by the same letter are not significantly different at the 1% level.

Table 1 indicates that P accumulation in roots and shoots of plants varied with the treatments. Irrespective of cultivar, maximum P:Fe ratio occurred in treatments without Fe, followed by inorganic Fe^{3+} and least with FeEDDHA. On the other hand, maximum Fe level was observed in the shoot of plants with FeEDDHA, next with inorganic Fe^{3+} and last without Fe, thus causing a significant difference in P:Fe ratio of the shoots.

It can be concluded that the cultivars of sunflower used in this experiment could utilize inorganic Fe^{3+} as well as FeEDDHA, and the phosphate accumulation or inactivation did not appear to be a problem. As such the cultivation of sunflower cultivars tested in this study should not bear any problem with respect to Fe nutrition.

LITERATURE CITED

1. Bell, W.D., L. Bogorad and W.L. McIlrath. 1958. Response of the yellow stripe maize mutant (ys) to ferrous and ferric iron. Bot. Gaz. 120: 36-39.
2. Branton, D. and L. Jacobsen. 1961. Iron transport in pea plants. Plant Physiol. 37: 539-545.
3. Brown, J.C., L.O. Tiffin, R.S. Holmes , A.W. Specht and J.W. Resnicky. 1959. Internal inactivation of iron in soybean as affected by root growth medium. Soil Sci. 87: 89-94.
4. Brown, J.C., R.C. Holmes and L.O. Tiffin. 1961. Iron chlorosis in soybean as related to the genotypes of root stalk. III. Chlorosis, susceptibility and reductive capacity at the root. Soil Sci. 91: 127-132.
5. Brown, J.C., C.R. Weber and B.E. Caldwell. 1967. Efficient and inefficient use of iron by two soybean genotypes and their isolines. Agron. J. 59: 459-462.

6. Brown, J.C. and W.D. Bell. 1969. Iron uptake dependent upon genotype of corn. Soil Sci. Soc. Amer. Proc. 33:99-101.

7. Brown, J.C. and J.E. Ambler. 1970. Further characterization of iron uptake in two genotypes of corn. Soil Sci. Soc. Amer. Proc. 34: 249-252.

8. Brown, J.C. and R.L. Chaney, 1971. Effect of iron on the transport of citrate into the xylem of soybean and tomatoes. Plant Physiol. 47: 836-840.

9. Brown, J.C. 1972. Competition between phosphate and the plant for Fe from Fe^{2+} ferrozine. Agron. J. 64: 240-243.

10. Brown, J.C., J.E. Ambler, R.L. Chaney and C.D. Foy. 1972. Differential responses of plant genotype to micronutrients. *In* Micronutrient in Agriculture. J.J. Mortredt, P.M. Giordino and W.L. Lindsay (eds). Soil Sci. Soc. Amer., Madison, Wis. pp. 389-418.

11. DeKock, P.C. and A.W. Hali. 1955. The phosphorus-Iron relationship in genetical chlorosis. Plant Physiol. 55: 293-295.

12. Jackson, M.L. 1958. Phosphorus determination for soils. In Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs. New Jersey, pp. 132-134.

13. Jenny, H. 1965. Die Grenzzone von Wurzel und Boden in Ihrer Bedeutung fur die Aufnahme vón Eisen aus Kalkhaltigen Boden. Die Wein-Wissenschaft 20: 49-61.

14. Kashirad, A., H. Marschner and C. Richter. 1973. Absorption and translocation of 59 Fe from various parts of the corn root. Z. Pflanzenernahr. Bodenk. 134: 136-147.

15. Kashirad, A. and H. Marschner. 1974. Iron nutrition of sunflower and corn plants in mono and mixed culture. Plant and Soil 41: 91-101.

16. Kashirad, A. and H. Marschner. 1974. Effect of pH and phosphate on iron nutrition of sunflower and corn plants. Agrochimica 18: 497-508.

17. Nagarajah, S. and A. Ulrich. 1966 Iron nutrition of sugar beet plant in relation to growth, mineral balance and riboflavin formation. Soil Sci. 102: 399-407.

18. Ordurukwe, S.O. and D.N. Maynard. 1969. Mechanism of the differential response of Wf_Q and Oh_4OB corn seedlings to iron nutrition. Agron. J. 61:694-697.

19. Venkat Raju, K., H. Marschner and V. Romheld. 1972. Studies on the effect of iron supply on iron uptake, substrate pH and production and release of organic acids and riboflavin by sunflower plants. Z. Pflanzenernahr. Bodenk. 132: 177-190.
20. Venkat Raju, K. and H. Marschner. 1972. Mechanism of regulation of iron uptake from relatively insoluble iron compounds by sunflower plant. Z. Pflanzenernahr. Bodenk. 133: 227-240.
21. Wallace, A., E.T. Frolich and A. Elgazzar. 1968. Root excretions in iron-deficient tobacco plants and possible effects on iron nutrition. *In* sotopes and Radiation in Soil Organic Matter Studies. Proc. Symp IAEA/FAO, 1968 Wien, pp. 385-396.
22. Welkei, G.W. and G.W. Miller. 1960. Iron nutrition of *Nicotiana tabacum* L. in relation to riboflavin, riboflavin-5-phosphate and flavin adenine content. Plant Physiol. 35: 516-520.