AT0000031

SUITABILITY OF SOME GROWTH CHARACTERISTICS TO INDICATE PHYTOTOXICITY IN POT EXPERIMENTS ON MAIZE TEST PLANTS

KLARA BUJTÁS

Research Institute for Soil Science and Agricultural Chemistry (RISSAC)
of the Hungarian Academy of Sciences
H-1022 Budapest, Herman O. ut 15. HUNGARY

Summary

Assessment of phytotoxic conditions is often based on measuring the dry matter production of plants, although other growth characteristics may be more sensitive indicators of toxic circumstances. Purpose of this study was to evaluate the suitability of such variables as fresh weight, dry matter accumulation of shoots, longitudinal growth of leaves, and correlations between these variables for quantifying phytotoxicity caused by provocative rates of a lenacil-based herbicide. Impact of soil texture and soil pH on the manifestation of toxic symptoms were also investigated in a pot experiment on three soil types with maize (*Zea mays* L. cv. Carla) as test plant. Although the external circumstances were much different from field conditions, the observed differences in the phytotoxicity on the three soils were consistent with the application recommendations of the herbicide. High toxicities were observed on acidic sandy soil, and less on a similarly acidic soil of heavier texture. In contrast, slight stimulations were observed on chernozem soil at application rates lower than or corresponding to recommended field rates. Sum of the lengths of the leaves was a relatively sensitive indicator of bioactivity, showing cumulatively the effects observed for the individual leaves. Correlations between fresh weight/dry matter accumulation and fresh weight/sum of the lengths of leaves were shown to be linear over the application range, with slopes depending mostly on soil texture, and less so on soil pH. The results indicate that the suitability of the investigated variables for assessing phytotoxicity may be different on the different soil types.

Introduction

Phytotoxicity was described by Chang et al. (1992) as an intoxication of living plants by substances present in the growth medium, when these substances are taken up and accumulated in plant tissues in such amounts which are sufficiently high to cause toxic symptoms. Such an approach requires determination of toxicity threshold plant tissue concentrations of the substance, as well as a distinction of the specific symptoms caused by the substance from those caused by other disorders. Knowledge of the biochemical-physiological processes which are primarily damaged by the substance would be also essential.

This definition of phytotoxicity involves that the substance must enter the living cells and accumulate in the plant tissues to exert long-time effects. During the uptake and transport through the different compartments in the plant tissues the substance may interact with the biological membranes. As a consequence, several physiological processes may be damaged. Mineral nutrition, water uptake and water household management of the plants are much influenced by substances acting on the plasmalemma, which may be the primary site of toxic action in many cases. We found that toxic amounts of several trace elements, e.g. Cu, Cr, and Hg inhibit K uptake of young seminal roots (Bujtás and Cseh 1981, 1983). Also, water content of shoots and roots and average root diameters reflected the quantitative differences in the bioactivity in a group of structurally related nonionic surfactants (Bujtás and Cserháti 1993). We concluded that such variables as rate of K uptake, fresh weight and the geometry of intensively developing plant parts may be more sensitive indicators of toxic circumstances at the early stages of plant development or at initial stages of the toxic action, than reduction of dry matter accumulation, which is one of the most widely used variables for assessing phytotoxicity.

Purpose of the study presented here was to evaluate the applicability of growth characteristics, such as fresh weight and dry matter accumulation of shoots, and longitudinal growth of leaves, for quantifying phytotoxicity caused by provocative rates of a lenacil-based herbicide, ADOL 80 WP. Impacts of soil texture and soil pH on manifestation of the phytotoxicity were also investigated.

ADOL 80 WP is recommended to control dicots in several crops (sugar beet, maize, strawberry, yellow lupin). It is applied presowing or preemergent at rates mostly in the range between 0.6 and 2.2 kg/ha, depending on the crop, and on the texture and organic matter content of the soil. Its active ingredient, the lenacil, belongs to the uracil-type herbicides, and is a known photosynthesis-inhibitor (Moreland and Hilton 1976). However, there is a limited amount of information about its effects on other processes, such as synthesis of nucleic acids (Matolcsy et al. 1988).

Materials and methods

A pot experiment was carried out with maize (*Zea mays* L. cv. Carla) as test plant. Three soil types were selected: an acidic sandy soil, a similarly acidic soil of a heavier texture, containing more silt and clay fractions, and a neutral soil, whose texture was similar to that of the second soil. As a consequence of this selection the soils could be matched in pairs according to both texture and pH. Soil properties are shown in Table 1.

Table 1. Soil properties

	NL (Nyirlugos)	**RA** (Ragály)	**NH** (Nagyhörcsök)
soil type	Entisol, Psamment	Alfisol, Udalf	Mollisol, Boroll
Hungarian classification	light, acidic brown forest soil	brown forest soil with clay illuviation	pseudomyceliar chernozem
pH_{KCl}	3.74	2.98	7.07
$CaCO_3$ %	0	0	4.5
organic matter %	1.16	2.15	3.85
texture sand (>0.05) %	93.6	22.3	27.3
silt (0.05-0.002) %	6.4	62.9	67.5
clay (<0.002) %	0	14.8	5.2
cation exchange capacity (meq/100 g)	4.5	26.2	32.2
base saturation %	24.9	32.3	100

Seven plants were grown in 2-kg-pots. The herbicide was applied preemergent, at rates 0 (control), 0.08, 0.10, 0.15, 0.20 and 0.80 g/m^2, representing a range a rates from lower than to highly exceeding the recommended field rates. The experimental design was random block, with three paralels. We emphasize that although the plants were kept outdoor, circumstances were much different from field conditions. The pots were protected from rain by a movable cover. Since the weather was very hot and sunny from the second week of the experiment onwards, and daily maximum temperatures ranged generally between 35 and 37 °C, daily irrigation was applied as needed, supplying the plants with much more water than available under usual Hungarian field conditions.

Plants were sampled destructively at 28, 40 and 100 days after sowing. Fresh weight of shoots, length of individual leaves, and dry weight of shoots were measured. The data were used to calculate sum of the lengths of individual leaves, SLL. Accumulation of dry matter was expressed also as percentage of fresh weight. Correlations between fresh and dry weights, and between fresh weight and SLL's, respectively, were approximated using linear relationships. Results of the first sampling are presented.

Results and discussion

All the three measured variables, fresh weight, dry matter accumulation, and length of individual leaves decreased when the application rate increased. Substantial differences

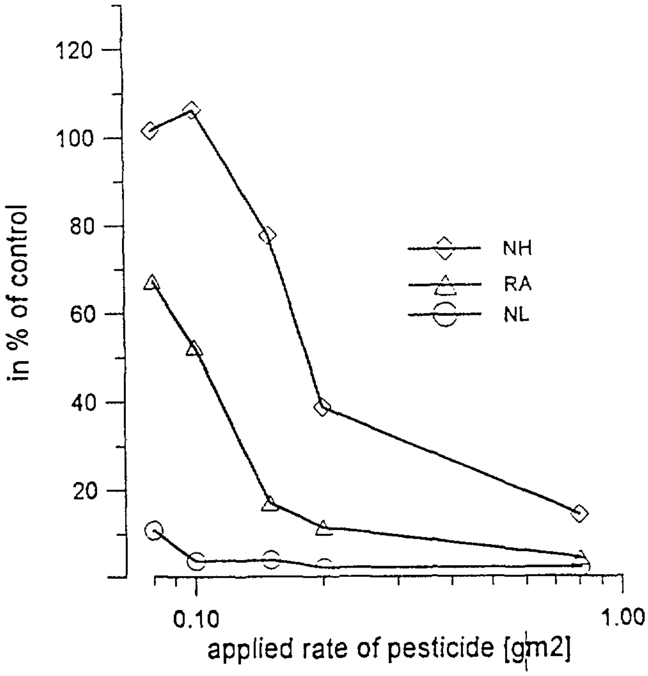

Fig. 1. Fresh weight of maize shoots

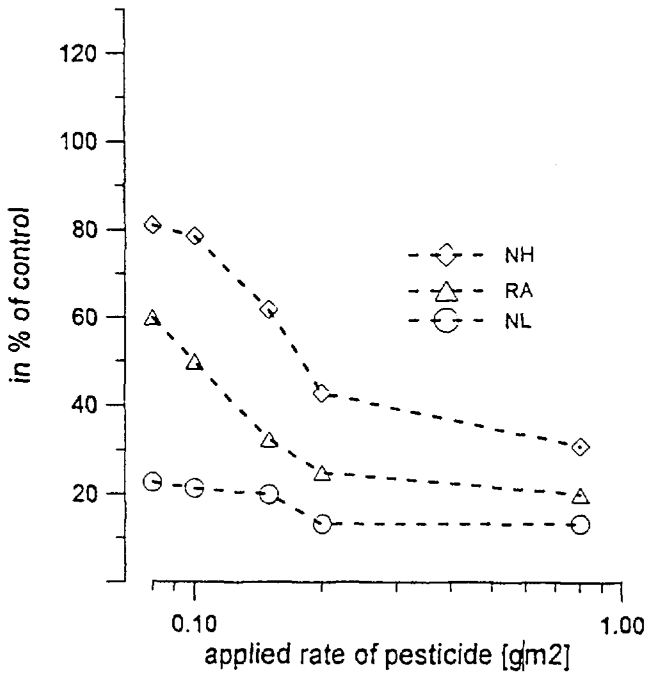

Fig. 2. Dry weight of maize shoots

were observed for the three soils. Plants grown on the acidic sandy soil were seriously damaged, dry matter accumulation was as low as 23%, fresh weight only 11%, as compared to control plants on this soil. Plants grown on the neutral chernozem soil at the two lower application rates were damaged the least, their fresh weights even exceeded slightly that of the controls (Figs. 1. and 2.).

Lengths of the individual leaves showed similar features: a strong growth inhibition was observed over the entire application range for the plants grown in the acidic sandy soil, and a slight growth stimulation was found on the chernozem soil in those treatments which corresponded to the recommended field application rates of the herbicide (Table 2).

Table 2. Average length of the maize leaves 28 days after sowing [cm]

applied rate [kg/ha]	1.leaf	2.leaf	3.leaf	4.leaf	5.leaf	6.leaf	7.leaf	total length
NL (light, acidic brown forest soil, Nyirlugos)								
0	4.0	18.5	32.3	47.2	53.0	39.4	20.5	215.0
0.08	7.4	18.2	29.0	33.0	16.5	0.7	-	104.8
0.10	7.0	17.6	28.7	29.0	10.4	-	-	92.7
0.15	7.7	17.7	26.6	27.4	8.8	-	-	88.3
0.20	7.0	16.7	23.5	20.1	1.3	-	-	68.6
0.80	7.0	15.8	21.9	18.3	-	-	-	63.0
RA (brown forest soil with clay illuviation, Ragály)								
0	5.1	14.5	24.6	33.6	32.1	17.6	5.1	132.6
0.08	5.6	14.8	24.6	31.9	25.6	10.9	3.8	117.1
0.10	5.3	14.6	24.9	31.2	23.7	8.9	-	108.5
0.15	5.0	14.9	24.3	26.6	11.8	-	-	82.7
0.20	6.0	14.5	22.0	22.2	6.1	-	-	70.8
0.80	5.0	13.5	20.1	16.5	0.4	-	-	55.6
NH (pseudomyceliar chernozem, Nagyhörcsök)								
0	6.5	16.8	27.4	35.2	29.1	12.1	-	127.0
0.08	7.2	17.4	28.7	36.4	32.1	19.2	-	141.0
0.10	7.2	17.8	30.0	40.1	37.0	21.1	-	153.2
0.15	7.0	18.1	30.4	38.6	31.8	9.1	-	134.9
0.20	6.4	17.0	27.9	32.8	20.4	0.6	-	105.0
0.80	6.5	16.8	25.8	26.3	9.5	-	-	84.9

Growth of the first, second and third leaves were not much affected even in the acidic sandy soil, although these leaves had to grow through the soil layer onto which the herbicide was sprayed before the plants emerged. Small growth effects were observed on the fourth leaves, but the significant stimulations and inhibitions appeared only on the fifth and subsequent leaves. Data obtained at the second sampling (not presented here) showed no recovery of the already inhibited leaves as the experiment progressed in time. Thus it was not very probable that by the time of the first sampling the growth of the first three leaves recovered quickly after an initial inhibition. This result indicates that only those leaves were affected, which developed when the photosynthesis had already been damaged. This hypothesis is supported by data of dry matter accumulation. On the other hand, a slight decrease of dry matter accumulation, which was observed on the chernozem soil did not lead to growth inhibition. When the lengths of the individual leaves were added for each plant, and averages of these sums (SLL's) were calculated for each treatment, this variable showed cumulatively the inhibitions and stimulations observed for the individual leaves. As a consequence, SLL's were more sensitive indicators of the bioactivity of the herbicide, than the conventionally measured total plant height.

Relative dry matter accumulation, when calculated as percentage of fresh weight, is generally very stable under suitable external conditions, and is characteristic for the different plant parts and for the different developmental stages. Changed values may

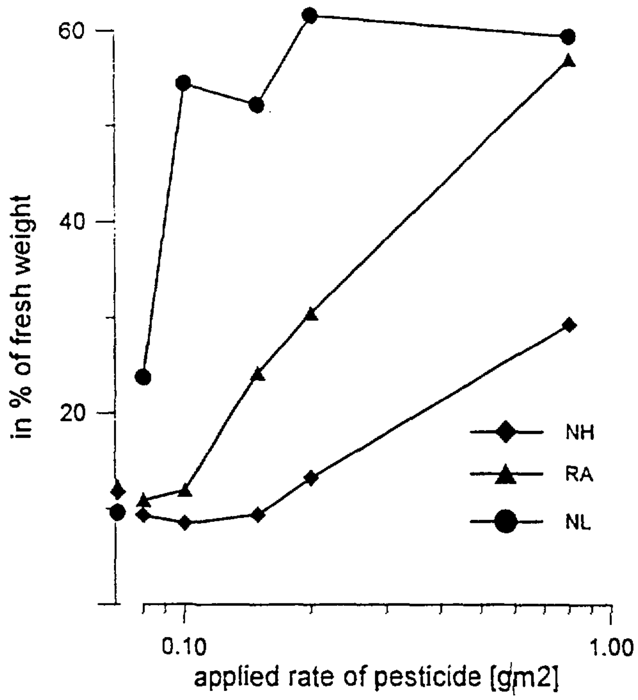

Fig.3. Relative dry matter accumulation calculated as percentage of fresh weight

indicate serious disturbancies in the water relations of the plants. Such situation was observed for the plants grown on the acidic sandy soil, where a very high relative dry matter content was found over the entire application range (Fig.3.). Relative dry matter contents of plants grown on those two soils, which had heavier texture, were near to or even lower than control values, especially so at the lower application rates. This result indicates smaller, if any disturbance in the water relations of the plants grown on these soils.

Correlations between fresh and dry weights, and between fresh weights and SLL's, respectively, were approximated using linear relationships (Figs.4. and 5.). The R^2 values show very high correlations for the two heavier-textured soils, and less so for the acidic

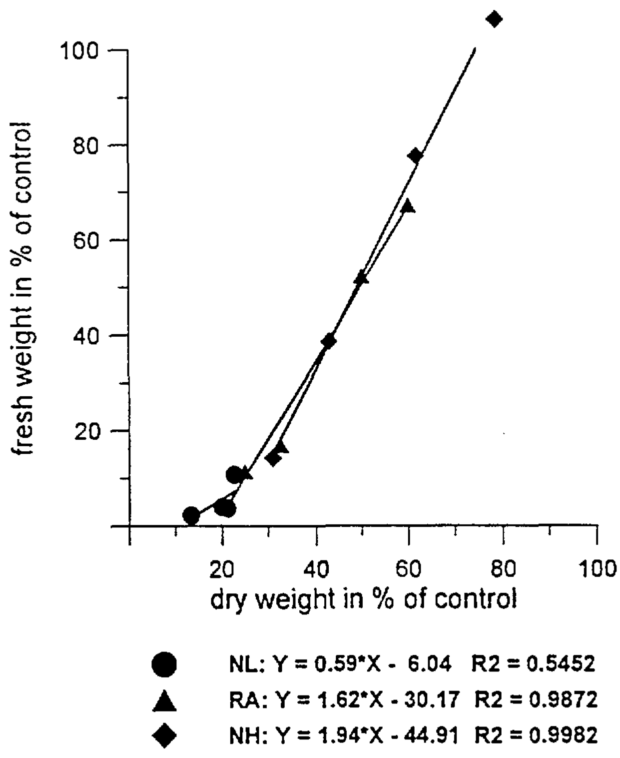

Fig.4. Fresh weight vs dry matter accumulation of maize shoots

sandy soil. From the slopes of the lines we conclude that the extent of changes in the fresh weight of the shoots was greater than either for dry matter accumulation or for the SLL's. This result was observed only for the two heavier-textured soils, where fresh weight seems to be the most suitable among the selected variables to quantify phytotoxicity of the lenacil. In contrast, fresh weight was less sensitive to increasing herbicide rates, than dry matter accumulation or SLL on the acidic sandy soil.

Since the correlations show much more similarity for the two heavier-textured soils, than for the two acidic soils, we suggest that the soil texture may have more impact on the phytotoxicity of the lenacil, than soil pH. We emphasize that at present a limited amount of information was available from the experiment conducted only on three soil types to support this hypothesis.

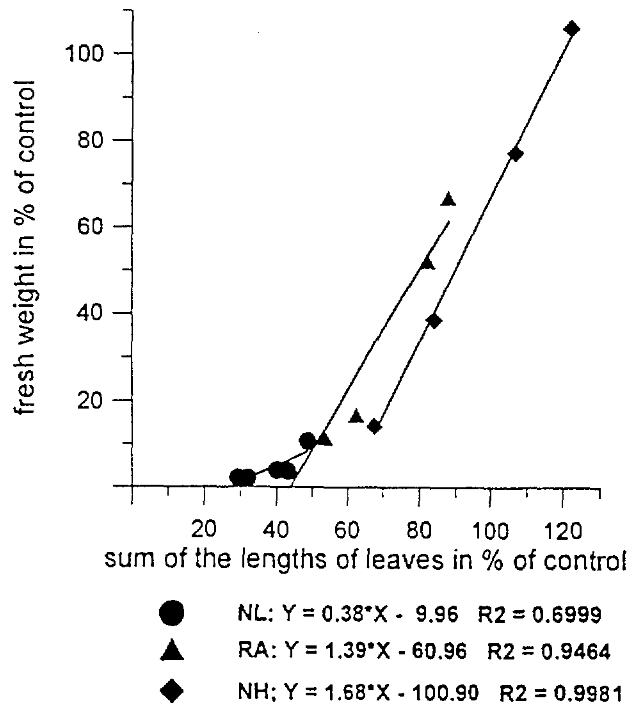

Fig.5. Fresh weight vs sum of the lengths of the individual leaves (SLL) in maize

We must also note that although our experimental circumstances were much different from normal agricultural practice, the observed differences in the extent of toxicity for the three soils, and for each of the measured and calculated variables were consistent with the application recommendations of the herbicide.

Acknowledgement

This research was supported by Richter Gedeon Chemical Works Ltd., Hungary, under contract No. 904038.

Literature

Bujtás,C. and Cseh,E. (1981) Effect of heavy metals and chelating agents on potassium uptake of cereal roots. Plant and Soil 63: 97-100.

Bujtás,C. and Cseh,E. (1983) Interpretation of different action of Cu and Hg on K^+ uptake system in wheat. In: Membrane Transport in Plants (Eds.:Cram,W.J.-Janácek,K.-Rybová,R.-Sigler,K.) pp.476. Academia, Praha (1984).

Bujtás,K.- Cserháti,T. (1993) Characterization of effects of nonionic surfactants on growth and root characteristics of wheat seedlings. Book of Abstracts of XXIIIrd Annual Meeting of ESNA, Halle, Germany, SozEp Hefte 4/1993: 100.

Chang,A.C.; Granato,T.C. and Page,A.L. (1992) A methodology for establishing phytotoxicity criteria for chromium, copper, nickel, and zinc in agricultural land application of municipal sewage sludge. J.Environ.Qual. 21: 521-536.

Moreland,D.E. and Hilton,J.L. (1976) Actions on Photosynthetic Systems. In: Herbicides. Physiology, Biochemistry, Ecology. (Ed.: Audus,J.L.) Vol.1. pp. 493-523. Academic Press, London-New York-San Francisco.

Matolcsy,G.; Nádasy,M. and Andriska,V. (1988) Pesticide Chemistry. Akadémiai Kiadó, Budapest.