Relation between multi-nutrient soil tests and boron in barley

J. Matula, M. Pechová

Research Institute of Crop Production, Prague-Ruzyne, Czech Republic

ABSTRACT

The aim of study was to verify a possibility of adding boron to multi-nutrient soil tests: Mehlich 3, water (1:5) and 0.5M NH_4-acetate extraction. Thirty-six different soils from topsoils of agriculturally farmed field were used for the study. The basic set of 36 soils was doubled when the same soil samples with gypsum addition at an equivalent dose 2 t Ca/ha were used. The closest correspondence between B in soil (n = 72) and B in plant was found out by the NH_4-acetate soil test. This test proved its good universality and independence on a radical intervention in soil chemistry by gypsum treatment. It responded to an increase in B-availability to plants after gypsum treatment of soil. The adjustment of NH_4-acetate boron by the percentage difference between the actual and the desired pH of soil improved the closeness of the correlation. Although the H_2O soil test showed its lower universality, it is assumed to use the H_2O soil test for prediction of B-status in soil when the history of previous fertilisation of the field will be known. The Mehlich 3 soil test did not prove to be suitable for diagnostics of B-status in soil.

Keywords: soil tests; Mehlich 3; water extraction; ammonium acetate extraction; boron; barley

The majority of soils in the CR do not provide adequate boron nutrition to agricultural crops. Crops markedly differ in their requirements for boron; in general, dicotyledonous plants have higher requirements than monocotyledonous ones. A specific feature of the element boron is an extremely small difference between its deficiency and its surplus – toxicity. This aspect should always be considered for the correction of plant nutrition with boron aimed at the overall harmonisation of plant nutrition. Plant nutrition is a complex factor the farmer can influence actively, contrary to environmental factors connected with weather conditions. The complexity of the factor plant nutrition is confirmed by the fact that its positive effects are fully expressed only if all major and trace nutrients participate at relevant levels and mutual proportions, i.e. if they are in harmony.

An important instrument for realisation of effective plant nutrition is diagnostics, especially preventive diagnostics, which primarily comprises soil tests before the own vegetation of the crop. The basic condition of an agronomic use of soil tests for crop nutrition optimisation is a good correspondence between soil tests and biological availability of nutrients.

Hot-water extraction of boron from the soil (SPAC 1999) is a conventional soil test to evaluate the boron status of soils. It is however a single-nutrient soil test, implying many methodical difficulties that contribute to standardisation weaknesses of the test. Therefore the aim of our study was to verify a possibility of adding boron to multi-nutrient soil tests and to extend the complexity of information on the nutrient status of soils for the needs of effective management of utilisation of fertiliser and soil reserve nutrients.

MATERIAL AND METHODS

Thirty-six soils from topsoils of agriculturally farmed fields in 22 localities of the CR were used for the study. Bulk samples of soil were air-dried and homogenised by screening through a 2-mm sieve. Table 1 shows some agrochemical characteristics of the basic set of soils. Three soil tests were used to evaluate the nutrient status of soils: Mehlich 3 (Zbíral 2002), water extraction of soils at a 1:5 ratio w/v (SPAC 1999) and extraction with 0.5M ammonium acetate with the addition of ammonium fluoride (Matula 1996). The ICP-OES

Supported by the Ministry of Agriculture of the Czech Republic, Project No. MZe-00027006-01.

Table 1. Information about agrochemical characteristics of the experimental set of soils

Soil	pH 0.2M KCl	C_{ox} (Sims and Haby 1971)	CEC nmol/kg (Matula 1996)	Determined B by soil tests (mg/kg)			NH_4-acetate (Matula 1996)		
				Mehlich 3	water (1:5)	NH_4-acetate	K (mg/kg)	Mg (mg/kg)	P_{index}
1	6.06	1.47	120	0.23	0.226	0.25	164	144	1816
2	5.88	1.31	128	0.25	0.204	0.16	177	213	2962
3	6.89	1.71	108	0.15	0.388	0.39	199	37	494
4	6.80	2.32	256	0.30	0.797	0.70	821	184	4383
5	6.16	1.42	128	0.15	0.313	0.32	172	83	2354
6	6.36	2.17	186	0.21	0.323	0.40	257	163	3793
7	6.69	1.38	124	0.22	0.170	0.21	184	96	1950
8	6.13	1.86	136	0.18	0.080	0.08	133	139	3267
9	4.08	1.85	140	0.22	0.099	0.02	103	174	1730
10	5.06	2.40	160	0.21	0.147	0.11	156	211	1442
11	5.33	1.75	142	0.15	0.182	0.12	87	187	653
12	4.94	1.84	135	0.18	0.115	0.07	271	62	2941
13	6.63	1.60	120	0.21	0.143	0.24	121	50	2054
14	5.35	2.55	179	0.17	0.251	0.27	435	172	1719
15	5.84	1.60	126	0.19	0.203	0.14	303	156	1740
16	5.67	1.50	103	0.17	0.214	0.19	175	124	2230
17	4.84	1.20	109	0.12	0.286	0.16	122	151	1398
18	6.38	1.72	116	0.20	0.078	0.10	278	59	3151
19	5.09	2.10	136	0.11	0.129	0.12	184	108	2399
20	5.90	2.61	113	0.18	0.136	0.10	162	91	917
21	5.73	2.89	133	0.15	0.104	0.11	315	73	3220
22	5.05	2.49	146	0.16	0.140	0.10	334	128	3441
23	5.62	1.91	123	0.14	0.091	0.09	162	76	1986
24	6.22	1.96	151	0.21	0.187	0.10	166	195	1374
25	5.76	2.33	135	0.23	0.161	0.09	229	99	2853
26	5.96	2.18	117	0.20	0.162	0.15	215	103	5179
27	5.76	2.30	113	0.22	0.154	0.13	266	103	6517
28	5.43	2.11	219	0.29	0.261	0.15	222	430	1207
29	5.32	1.73	103	0.22	0.193	0.09	164	101	2118
30	5.60	2.09	116	0.14	0.140	0.08	131	76	1798
31	5.60	1.63	135	0.17	0.204	0.16	115	120	1253
32	6.94	2.20	124	0.33	0.110	0.35	85	22	396
33	6.10	2.37	112	0.21	0.126	0.10	174	87	3407
34	5.35	1.70	97	0.15	0.082	0.01	82	131	1403
35	4.50	2.14	105	0.14	0.094	0.05	236	99	3577
36	5.83	2.10	95	0.29	0.167	0.16	532	95	3408
Mean	5.75	1.96	133	0.20	0.190	0.17	220	126	1310
CV (%)	11.5	20.6	24.8	26.4	66.9	78.7	63.7	56.4	54.5

technique on a Thermo Jarrell Ash Trace Scan Analyser was used to detect boron and other nutrients in extracts.

The basic set of 36 soils was doubled when the same soil samples with gypsum addition at an equivalent dose of 2 t Ca per hectare were used. The purpose was to verify the universality of soil test information about boron after a large intervention in the soil by gypsum treatment. The whole set (n = 72) was studied for biologically available boron on barley as the test crop. The method of testing biological availability was similar to that in Matula (2004).

Statistical programme GraphPad PRISM, Ca., USA, version 3.0, and Microsoft Excel 2000 were used to evaluate the experimental results.

RESULTS AND DISCUSSION

Figures 1–4 show the relations between boron diagnosed by soil tests and boron in barley shoots. The necessary correspondence with boron content in barley was not proven when the Mehlich 3 soil test was used; practically, it excludes the use of this test for the prediction of boron status in soils. A substantially different situation was found in the other two soil tests where the results indicated a possibility of using these tests for the diagnostics of boron reserve in soils.

The analysis of the point field in Figure 3, i.e. of the relation between the soil extraction with 0.5M ammonium acetate with addition of NH_4F (pH = 7) and the plant, shows that the closeness of the relation is markedly disturbed by soils 3, 4 and 32 (Table 1). Soils 3 and 32 show similar characteristics. They are light soils with low sorption capacity (CEC value) but with the extremely high value of exchange pH. An extremely low value of P index is another common characteristic of these soils differing from the other soils of the set. On the contrary, soil No. 4 had a high CEC value and an extremely high reserve of exchange potassium. The evaluation of deviations from the convenient range of soil pH that is applied to an optimisation of soil liming (Matula and Pechová 2002) is a part of the NH_4-acetate soil test (locally called KVK-UF test). A soil species defined by the determined value of soil CEC is used for the estimation of convenient soil pH. It generally applies to boron that its possible uptake from the soil is markedly influenced by the pH value of soil (Russell 1973, Tisdale and Nelson 1975, Mengel and Kirkby 1982). There arises a question about the NH_4-acetate soil test whether the principle of the definition of convenient soil pH and its deviations from reality could be used for the correction of boron values determined in soil by this test. A percentage deviation ± from the convenient pH of soil was used tentatively for the correction of

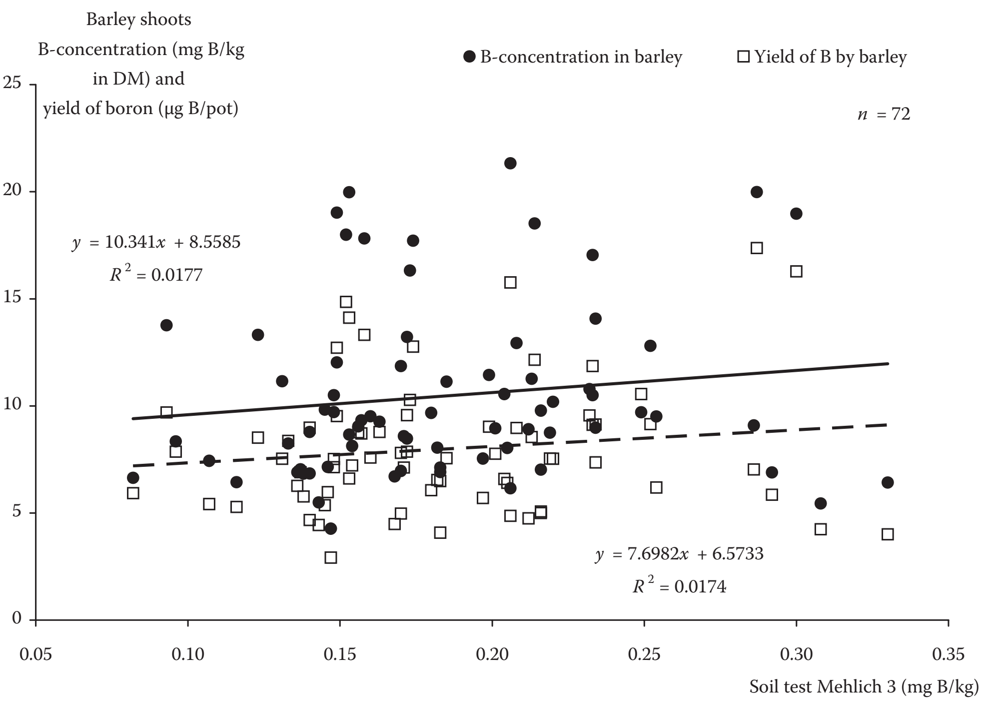

Figure 1. Diagram of B-concentration in shoots of barley and yield of boron by barley shoots versus Mehlich 3 soil test

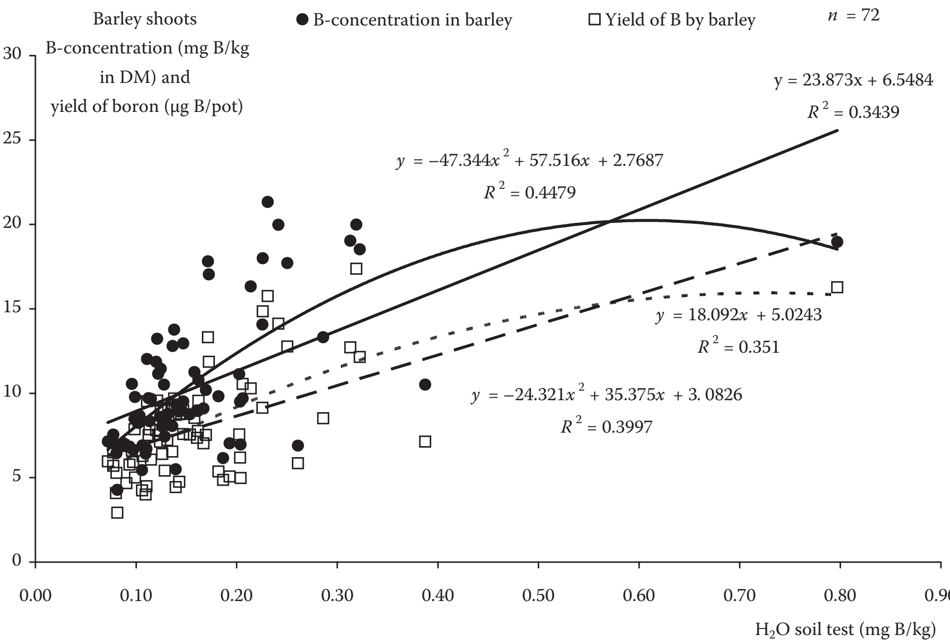

Figure 2. Relationship between the H_2O (1:5) B-soil test and boron in barley shoots

determined boron content in soil (i.e. determined value of B – [± corrected value of B by the level of % deviation of soil pH from an optimum]). After the correction of determined boron content in soil by the above-described method the closeness of the soil-plant relation increased (Figure 4). We assume that it will be useful to continue work on the form of correction of determined boron in soil in relation to soil chemistry.

The all used extraction methods showed an important influence of gypsum treatment on boron extraction from soils (Matula and Pechová 2005). In Mehlich 3 and water extraction tests there was on average a significant decrease in B extractability from soils while extractability increased in the test with ammonium acetate extraction. The values of the average of the subset of soils after gypsum treatment were lower by

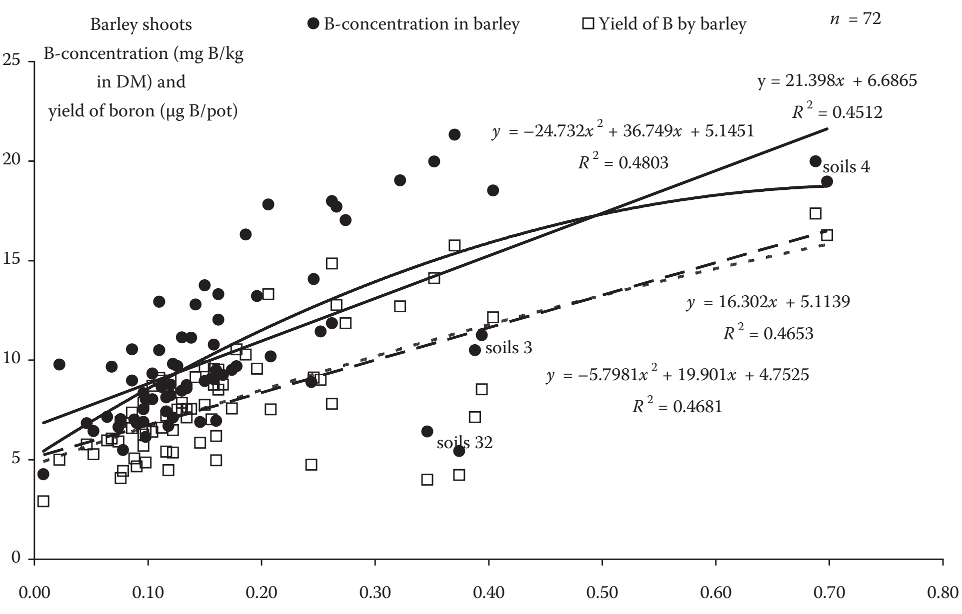

Figure 3. Relationship between the NH_4-acetate soil test and boron in barley shoots

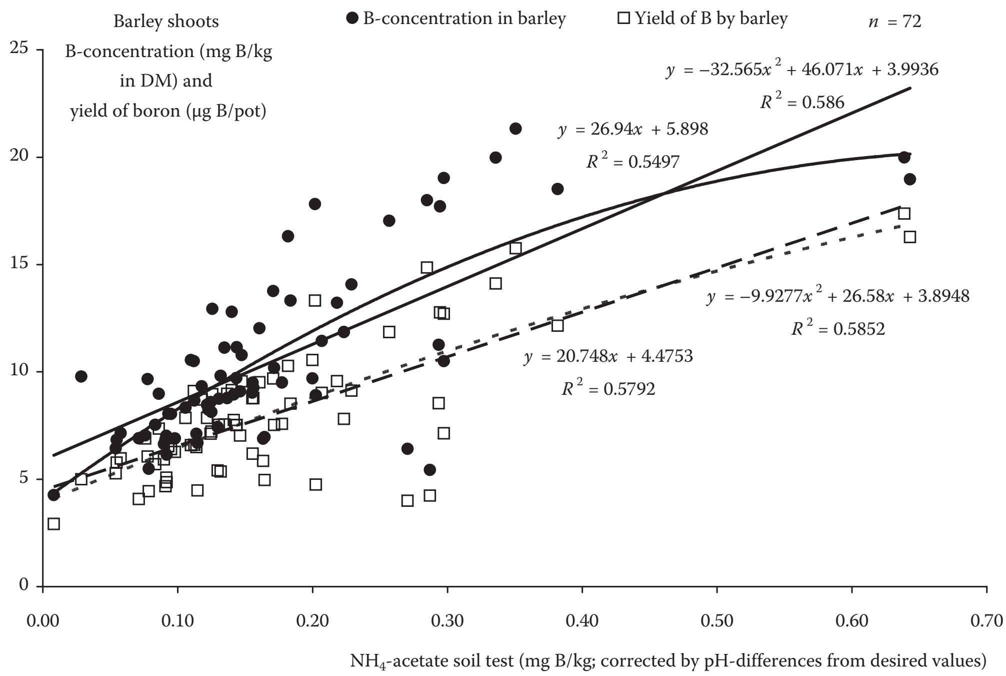

Figure 4. Relationship between corrected B-values of the NH_4-acetate soil test and boron in barley shoots

11% in Mehlich 3 test and by 28% in H_2O soil test compared to the control, i.e. the initial set of soils without gypsum treatment. In the NH_4-acetate soil test the average of the set was higher by 10% than in the control.

Table 2 illustrates the effect of gypsum treatment on boron variations in barley plants. The average of the boron concentration in barley was higher by 9% in the gypsum variant and the average of boron uptake by barley was higher by 25% compared to the control.

Among the used soil tests only the NH_4-acetate soil test responded to the stimulation of boron uptake by the plant in accordance with the effect of gypsum treatment. The NH_4-acetate soil test was found to be a more universal test, independent of the radical effect of gypsum treatment on soil chemistry. In fact, separate evaluation of subsets

Table 2. Influence of gypsum treatment on B-concentration in shoots of barley and yield of boron by barley shoots

Statistics	B-concentration in dry matter (mg B/kg)		B-yield by barley shoots (μg B/pot)	
	control	treated	control	treated
Minimum	4.270	5.440	2.920	4.240
Median	8.965	9.705	6.470	8.455
Maximum	19.03	21.33	16.28	17.37
Mean	9.972	10.960	7.114	8.876
SD	3.923	4.217	2.847	3.042
SE	0.654	0.703	0.475	0.507
Lower 95% *CI*	8.645	9.537	6.150	7.847
Upper 95% *CI*	11.30	12.39	8.077	9.905
CV%	39.3	38.5	40.0	34.3
Paired *t*-test, two-tailed, number of pairs = 36				
P-value	$P < 0.0001^{***}$		$P < 0.0001^{***}$	
Are means significantly different?	yes		yes	
Mean of differences	–0.9917		–1.763	
95% confidence interval	–1.364 to–0.619		–2.108 to–1.417	
R squared	0.455		0.754	

Table 3. Correlation of soil tests with boron in barley shoots

Soil test	Soil set	Correlation coefficient (*r*)	
		B-concentration in barley shoots	yield of boron by barley shoots
Mehlich 3	*n* = 72 (C + T)	0.1330	0.1319
	n = 36 C	0.0725	0.1436
	n = 36 T	0.1868	0.2207
Water extraction	*n* = 72 (C + T)	0.5865	0.5924
	n = 36 C	0.6643	0.7519
	n = 36 T	0.7972	0.8564
NH_4-acetate	*n* = 72 (C + T)	0.6717	0.6821
	n = 36 C	0.6780	0.7156
	n = 36 T	0.6757	0.7066
NH_4-acetate (B-values corrected by pH differences)	*n* = 72 (C + T)	0.7414	0.7610
	n = 36 C	0.7400	0.7843
	n = 36 T	0.7538	0.7885

C = control, basic set of soils, T = set of soils after gypsum treatment

(control variant and gypsum variant) in relation to the plant did not influence the closeness of the correlation (Table 3).

Although in the H_2O soil test a decrease in boron extractability after gypsum treatment was the most marked, quite a good correspondence between soil and plant was found in the whole set ($n = 72$). Logically, separate evaluation of subsets markedly increased the closeness of the correlation (Table 3). The universality of the information of the H_2O soil test is however lower. The knowledge of fertilisation (liming, gypsum treatment etc.) history could contribute to a more precise interpretation of the soil test result. Separate evaluation of the relation between soil and plant in Mehlich 3 soil test did not increase the closeness of the correlation (Table 3).

REFERENCES

Matula J. (1996): Determination of potassium, magnesium, phosphorus, manganese and cation exchange capacity for fertilizer recommendations used by Czech Union of Rapeseed Growers. Commun. Soil Sci. Plant Anal., *27*: 1679–1691.

Matula J. (2004): Barley response to the soil reserve of sulphur and ammonium sulphate in short-term experiments under controlled conditions of cultivation. Plant Soil Environ., *50*: 235–242.

Matula J., Pechová M. (2002): A simplified approach to liming and its evaluation. Commun. Soil Sci. Plant Anal., *33*: 2989–3006.

Matula J., Pechová M. (2005): Influence of gypsum treatment on extractability of nutrients from soils. Plant Soil Environ., *51*: 368–375.

Mengel K., Kirkby E.A. (1982): Principles of Plant Nutrition. 3rd ed. Int. Potash Inst. Bern, Switzerland.

Russell E.W. (1973): Soil Conditions and Plant Growth. 10th ed. Longman, London, New York.

Sims J.R., Haby V.A. (1971): Simplified colorimetric determination of soil organic matter. Soil Sci., *112*: 137–141.

Soil and Plant Analysis Council, Inc. SPAC (1999): Soil Analysis Handbook of Reference Methods. CRC Press, Boca Raton, London New York, Washington, D.C.

Tisdale S.L., Nelson W.L. (1975): Soil Fertility and Fertilizers. 3rd ed. Macmillan Publ. Co, Inc. New York, Collier Macmillan Publ., London.

Zbíral J. (2002): Analyses of Soils I. Central Institute for Supervising and Testing in Agriculture, Brno. (In Czech)

Received on February 2, 2006

Corresponding author:

Doc. Ing. Jiří Matula, CSc., Výzkumný ústav rostlinné výroby, Drnovská 507, 161 06 Praha 6-Ruzyně, Česká republika
phone: + 420 233 022 271, fax: + 420 233 310 636, e-mail: matula@vurv.cz