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EFFECT OF DIFFERENT Mo FERTILIZERS ON YIELD, CHEMICAL COMPOSITION OF SEED AND SOME PHYSIOLOGICAL PARAMETERS IN TWO SOYBEAN (Glycine Max. Merr.) CULTIVARS

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Abstract

The Mo nutrition has crucial influence on the metabolism of nitrogen and, consequently, the total metabolism of plants. Also, cobalt facilitates the process of nitrogen fixation, and it a cofactor of vitamin B_{12}, compounds of great importance in animal nutrition (Marschner, 1995). In this regard, we examined the effects of two fertilizers on the basis of Mo and Co with a similar chemical composition, but different pH values (7.1 and 5.5) on the yield, chemical composition of seeds and some physiological parameters (growth and photosynthesis) in two soybean cultivars ("Nena", ZP015) during two years. In "Nena" cultivar Mo/Co fertilizer with pH=7.1 does not affect the yield, while the Mo/Co fertilizer with pH 5.5 in the first season slightly raised the yield. In cultivar ZP015 both Mo/Co fertilizers had very favorable impact on yield during the second season, when they were optimal environmental conditions, in contrast to the unfavorable first season, when there were no significant differences in yield. Preliminary results of analysis of influence of Mo/Co fertilizer with pH 5.5 on the chemical composition of cultivar "Nena" during the first season indicated reduction of the seed content of Ca, Mg, Fe, Mn, oil, inorganic and phytic P, while increasing the content of Cu, Zn, GSH, phenolic and β-carotene, the same total phosphorus content, all against control plants. Preliminary results of analysis of influence of Mo/Co fertilizer with pH 5,5 on the seed chemical composition of soybean cultivar ZP015 during the first season indicated higher content of Ca, Mg, Fe, Cu, Zn, total phosphorus, Pi, GSH and phenolic, same content of oil, and lower content of phytic P and β-carotene, all against control plants. In same soybean cultivars results of analysis of influence of treatment of Mo/Co fertilizer with pH 7,1 on the seed chemical composition indicated lesser effects. In the first season of growing varieties "Nena", we see strong growth of the plants during vegetative and the first part of the generative growth stages of soybean plants, which coincides with intense photosynthetic activity. But in second part of the generative growth stages of soybean plants of the variety "Nena", we see a practical cessation of growth and reduced photosynthetic activity, the redistribution of weight towards the generative organs ("Pouring seed"). However, this process is somewhat slower in soybean plants treated with Mo/Co fertilizer with pH 7.1. But, as you note, this retention of photosynthetic competency in soybean plants treated with Mo/Co fertilizer with pH 7.1 has no effect on the final yield.

Key words: *Mo/Co fertilizer; pH value; yield; chemical composition; growth; photosynthesis*

Introduction

Molybdenum (Mo) is a transition element with multiple valence states (4^{th}, 5^{th} and 6^{th}), which indicates the different options of its apsorption and physiological function in plants (Marschner, 1995; Mendel& Hänsch, 2002, Schwarz& Mendel, 2006). So, Mo is a cofactor of nitrogenase, the key enzyme of symbiotic nitrogen fixation of atmospheric N_2 by legume bacteria and nitrate reductase, a key enzyme in the process of apsorption of nitrate in plants. Therefore, apsorption of Mo by plants influences the metabolism of nitrogen and, consequently, the total metabolism of plants. It is known that cobalt (Co) facilitates the process of nitrogen fixation, and it is the cofactor of vitamin B12, compounds of great importance in animal nutrition (Marschner, 1995).

Material and methods

Treatments were carried out with two Mo / Co fertilizers: a) „SPEEDY“ (Mo: 17%, Co: 1,7%; pH=7,1) and b) „Wuxal Extra CoMo“ (Mo: 16,5%, Co: 1,65%; pH=5,5) and they applied in the following doses per hektare: a) 150 ml of the „SPEEDY“ fertilizer dissolved in 400 liters of water (approximately 6,2 mM Mo and 0,4 mM Co) and b) 120 ml of the „Wuxal Extra CoMo“ (approximately 4,8 mM Mo and 0,3 mM Co). They were applied twice at the beginning of flowering (first half of June) on two soybean varieties, Nena and ZP015 (standard varieties). Experiments were performed in rain-fed conditions on chernozem soil type, at the vicinity of Zemun Polje in following seasons: 2008 (cv. Nena), 2012 (cv. ZP015), and 2013 (both cultivars). Seasons 2008 and 2013 were moderate for SE Europe in average temperature and precipitation amount, but 2012 was dry with high temperatures, particularly during flowering and grain filling period. In the 2008 season only for “Nena” cultivar we performed measurements of growth and photosynthesis. Parameters of growth, accumulation and redistribution of dry matter (LMR, SMR, RMR, ln TDW, RGR) were observed: 21.07.; 28.08. and 13.10. of 2008. in 10-12 reps (Poorter and Garnier, 1996). These parameters are defined by: De Groot and co-workers (2002) and Lambers and co-workers (1998). In addition, for reason of well-branched soybean habit, leaf aging and the importance of generative tissue of soybean (Vratarić, 1986), we introduced additional parameters redistribution of dry matter. These are: AtMR (mass fraction retaining tissue stem, branch, leaf stems), dLMR (mass fraction senescent and dead leaves), and GtMR (mass fraction of generative tissue: buds, flowers, pods, seeds). ΦPS_2 and ETR parameters of Chla fluorescence and photosynthesis (Maxwell and Johnson, 2000) were measureded by PAM 101/103 apparatus in the central part of the younger, fully developed trifoliate leaf in 21.07. and 28.08. of 2008. in 8 reps. After harvesting, average grain yield was assessed, and contents of different metabolites in soybean grain, such as inorganic phosphorus - P_i, phytate (by method of Dragičević et al., 2011) and β-carotene (colorimetrically, AACC, 1995), as well as the following elements: Fe, Mn, Zn, Mg (by Inductively Coupled Plasma - Optical Emission Spectrometry) and total P (colorimetrically, by method of Pollman, 1991). Because of the developments that we could not control the lost samples of soybean genotype "Nena" (view 2008), treated with fertilizer "Speedy" and intended for chemical analysis. Results are given as mean values with standard deviations ($\underline{X} \pm \sigma$).

Results and disscusion

In "Nena" cultivar Mo/Co fertilizer with pH of 7.1 (“Speedy”) does not affect the yield, while the Mo/Co fertilizer with pH 5.5 (“Wuxal extra CoMo”) in the 2008 season slightly raised the yield (Table 1). In cultivar ZP015 both Mo/Co fertilizers had very favorable impact on yield during the 2013 season, when they were optimal environmental conditions, in contrast to the unfavorable season of 2012, when there were no significant differences in yield (Table 2).

Table 1. Yield of soybean (G. max. Merr.; cv. “Nena”) grain per area unit (t/ ha)

Year of trial/ trial repeats	Yield of soybean grain (t/ ha) in a 2008 trial/ treatments			Yield of soybean grain (t/ ha) in a 2013 trial/ treatments		
	Control	Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)	Control	Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)
1	3,10	1,72	2,24	3,725	3,533	2,655
2	1,42	2,70	1,91	3,027	0,666	3,048
3	3,07	2,56	2,83	1,098	2,234	1,402
4	2,49	1,70	3,39	2,939	3,000	1,969
5	-	-	-	2,410	1,880	2,710
X±σ	2,52 ±0,79	2,17 ±0,53	2,59 ±0,65	2,640 ±0,981	2,263 ±1,102	2,357 ±0,662

Table 2. Yield of soybean (G. max. Merr.; cv. “ZP015”) grain per area unit (t/ ha)

Year of trial/ trial repeats	Yield of soybean grain (t/ ha) in a 2012 trial/ treatments			Yield of soybean grain (t/ ha) in a 2013 trial/ treatments		
	Control	Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)	Control	Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)
1	2,731	3,446	1,645	2,342	2,943	4,266
2	2,061	2,912	2,467	2,524	3,365	4,357
3	3,535	2,200	3,420	2,897	3,373	4,594
4	1,965	2,021	2,720	2,529	4,574	2,873
5	1,625	0,835	1,869	-	-	-
X±σ	2,383 ±0,758	2,283 ±0,990	2,424 ±0,706	2,573 ±0,233	3,564 ±0,703	4,022 ±0,779

Preliminary results of analysis of influence of Mo/Co fertilizer with pH 5.5 (“Wuxal extra CoMo”) on the chemical composition of cultivar "Nena" during the 2008 season indicated reduction of the seed content of Ca, Mg, Fe, Mn, oil, inorganic and phytic P, while increasing the content of Cu, Zn, GSH, phenolic and β-carotene, the same total phosphorus content, all against control plants (Table 3). Preliminary results of analysis of influence of Mo/Co fertilizer with pH 5,5 on the seed chemical composition of soybean cultivar ZP015 during the first season (2012) indicated higher content of Ca, Mg, Fe, Cu, Zn, total phosphorus, Pi, GSH and phenolic, same content of oil, and lower content of phytic P and β-carotene, all against control plants. In same soybean cultivars results of analysis of influence of treatment of Mo/Co fertilizer with pH 7,1 (“Speedy”) on the seed chemical composition indicated lesser effects (Table 3).

Table 3. Content of different elements, compounds and metabolits in soybean grain

Content of different elements, compounds and metabolits in soybean grain; $\underline{X}\pm\sigma$	Soybean cultivar/ year of trial				
	“Nena”/ 2008		ZP015/ 2012		
	treatment		treatment		
	control	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)	control	Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)	Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)
Ca (mg/g)	2165,62±75,13	2012,50±0,00	2287,50±17,68	2243,75±35,36	2375,00±97,23
Mg (mg/g)	2268,75±61,87	2221,88±13,26	2284,38±48,61	2253,12±30,94	2456,25±97,23
Fe (mg/g)	52,25±2,83	46,78±0,04	65,66±0,49	67,28±1,55	89,31±7,25
Cu (mg/g)	10,75±2,48	14,28±1,10	11,81±1,50	10,47±0,75	16,25±2,30
Mn (mg/g)	21,06±0,44	19,03±1,10	29,66±1,37	28,47±0,04	28,91±0,66
Zn (mg/g)	30,38±2,92	35,28±3,49	34,41±2,78	34,91±1,28	40,88±3,80
P (µg/g)	12554,56± 26,94	12516,46± 80,83	13430,90± 80,83	12459,31± 161,65	15012,13± 107,77
Pi (µg/g)	0,4120± 0,0241	0,3986± 0,0048	0,2983± 0,0086	0,4853± 0,0134	0,5547± 0,0054
P_{phytic} (µg/g)	16959,59± 128,67	16335,26± 51,57	12876,90± 471,98	11157,76± 375,23	10746,77± 647,97
Crude oil (%)	18,11	17,96	20,61	20,27	20,73
GSH (nmol/g)	614,95± 0,92	632,81± 6,95	421,20± 18,83	839,37± 3,60	1061,52± 3,13
β-karoten (µg/g)	16,49± 0,02	18,40± 0,04	13,53± 0,04	12,09± 0,17	11,78± 0,13
Total phenols (µg/g)	1288,89± 18,83	1344,68± 14,15	754,96± 26,24	1346,41± 14,90	1459,54± 5,70

In the first season (2008) of growing varieties "Nena", we see strong growth of the plants during vegetative and the first part of the generative growth stages of soybean plants, which coincides with intense photosynthetic activity (Table 5). But in second part of the generative growth stages of soybean plants of the variety "Nena", we see a practical cessation of growth (Table 5) and reduced photosynthetic activity (Table 6), the redistribution of weight towards the generative organs ("Pouring seed"; Table 4). However, this process is somewhat slower in soybean plants treated with Mo/Co fertilizer with pH 7.1. But, as you note, this retention of photosynthetic competency in soybean plants treated with Mo/Co fertilizer with pH 7.1 (Table 6) has no effect on the final yield (Table 1).

Table 4. Parameters of dry matter acumulation and partitioning between soybean (*G. max. Merr.*; cv. “Nena”) plant parts during different Mo treatment. 2008 trial

Parameters of dry matter acumulation and partitioning	Tretmants by different Mo fertilizers / time of plant harvesting								
	Control			Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)			Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)		
	21.07 (t_1)	28. 08 (t_2)	13. 10 (t_3)	21. 07 (t_1)	28. 08 (t_2)	13. 10 (t_3)	21. 07 (t_1)	28. 08 (t_2)	13. 10 (t_3)
LMR (g/g)	0,339± 0,030	0,260± 0,020	0,059± 0,087	0,333± 0,033	0,249± 0,041	0,018± 0,034	0,330± 0,036	0,260± 0,024	0,072± 0,108
RMR (g/g)	0,106± 0,014	0,087± 0,017	0,109± 0,029	0,094± 0,036	0,087± 0,013	0,128± 0,068	0,096± 0,022	0,101± 0,010	0,089± 0,022
SMR (g/g)	0,275± 0,033	0,238± 0,097	0,202± 0,075	0,275± 0,044	0,210± 0,063	0,168± 0,099	0,242± 0,082	0,275± 0,052	0,210± 0,054
AtMR (g/g)	0,468± 0,022	0,436± 0,049	0,332± 0,073	0,490± 0,036	0,438± 0,031	0,364± 0,101	0,493± 0,016	0,447± 0,047	0,362± 0,047
GtMR (g/g)	0,027± 0,003	0,184± 0,071	0,483± 0,128	0,026± 0,009	0,212± 0,049	0,481± 0,167	0,024± 0,003	0,178± 0,071	0,468± 0,146
dLMR (g/g)	0,059± 0,024	0,034± 0,027	0,012± 0,012	0,057± 0,032	0,016± 0,012	0,009± 0,009	0,062± 0,037	0,014± 0,009	0,013± 0,010
lnTDW (g)	2,85± 0,29	3,34± 0,85	3,40± 0,49	2,97± 0,28	3,65± 0,44	3,64± 0,77	2,83± 0,34	3,29± 0,42	3,45± 0,40

Table 5. RGR plant growth parameter of soybean (*G. max. Merr.*; cv. “Nena”) treated by different Mo fertilizers during various times. 2008 trial. RGR_1 plants: control plants; RGR_2 plants: plants treated with „Speedy“ fertilizer; RGR_3 plants: plants treated with „Wuxal extra CoMo“ fertilizer; (RGR = 1000 X ((ln TDW(t) – ln TDW(t-1))/ (t - (t-1)))

RGR ($mg\ g^{-1}\ day^{-1}$)	RGR values in soybean plants treated by different Mo fertilizers in various time intervals		
	RGR_1	RGR_2	RGR_3
RGR ($t_2 - t_1$)	14,00	19,43	13,14
RGR ($t_3 - t_2$)	1,33	-0,22	3,56

Table 6. PAR during measurements and parameters of Chla fluorescencije and photosynthesis (ΦPS_2, ETR) measured on the younger whole developed soybean (*G. max. Merr.*; cv. “Nena”) trifoliate leaves, treated by different Mo fertilizers during various times. 2008 trial

Parameter of Chla fluorescence and photosynthesis and the light during measurements	Tretmants by different Mo fertilizers / time of plant harvesting					
	Control		Speedy (6,2 mM Mo and 0,4 mM Co; pH=7,1)		Wuxal extra CoMo (4,8 mM Mo and 0,3 mM Co; pH=5,5)	
	21. 07	28. 08	21. 07	28. 08	21. 07	28. 08
ΦPS_2	0,686 ±0,072	0,568 ±0,105	0,648 ±0,067	0,644 ±0,069	0,654 ±0,044	0,519 ±0,120
ETR (µmol of elektrons $m^{-2}\ s^{-1}$)	404,63 ±115,80	332,80 ±88,08	392,96 ±103,20	393,23 ±64,51	438,52 ±49,33	335,98 ±96,72
PAR (µmol of photons $m^{-2}\ s^{-1}$)	1473,20 ±370,76	1475,25 ±347,83	1507,12 ±301,33	1529,50 ±225,68	1673,25 ±105,85	1608,50 ±177,10

Literature

American Association of Cereal Chemists Method (1995) Approved Methods of the AACC. in: AACC Method, The association: St. Paul, Minnesota, USA, pp. 14-50.

Dragičević V., Sredojević S., Perić V., Nišavić A. and M. Srebrić (2011) Validation study of a rapid colorimetric method for the determination of phytic acid and nonorganic phosphorus from grains. Acta Period. Technol.., 42: 11-21.

Kastori R. (1983) The Role of the Elements in Plant Nutrition. (on Serbian) Matica Srpska, Novi Sad, Serbia, pp. 350.

Lambers H., Poorter H. and M.M.I. Van Vuuren (1998) Research on variation in plant growth-introduction. in: INHERENT VARIATION IN PLANT GROWTH. Physiological mechanisms and ecological consequences. Lambers, H., Poorter, H. i Margaret M. I. Van Vuuren, eds., pp. 1-4, Backhuys, Leiden, Holland.

Marschner H. (1995) Mineral Nutrition of Higher Plants. 2nd edition, Academic Press, Harcourt Brace& Company Publishers, London, New York, pp. 889.

Mendel R.R. and G. Schwartz (2002) Molybdoenzymes and molybdenum cofactor in plants. J. Exp. Bot., Vol. 53, No. 375: 1689-1698.

Nešković M., Konjević R. and Lj. Ćulafić (2003) Plant Physiology. (on Serbian) NNK Internacional, Belgrade, Serbia, pp. 586.

Pollman R.M. (1991) Atomic absorption spectrophotometric determination of calcium and magnesium and colorimetric determination of phosphorus in cheese. Collaborative study. J. Assoc. Anal. Chem., 74(1):27-30.

Poorter, H. and Garnier, E. (1996) Plant growth analysis: evaluation of experimental design and computational methods. J. Exp. Bot., Vol. 47: 1343-1351.

Schwartz G. and R.R. Mendel (2006) Molybdenum Cofactor Biosynthesis and Molybdenum Enzymes. Ann. Revue of Plant Biol., 57: 623-647.

Vratarić M. (1986) Soybean production. (on Serbo-Croatian) NIRO „Zadrugar“, Sarajevo, Bosnia and Hercegovina, pp. 217.

De Groot C.C., Marcelis L.F.M., Van den Boogaard R. and H. Lambers (2002) Interactive effects of nitrogen and irradiance on growth and partitioning of dry-mass and nitrogen in young tomato plants. Funct. Plant Biol., 11: 1319-1328.

Maxwell K. and Johnson G. (2000) Chlorophyll fluorescence-a practical guide. J. Exp. Bot., Vol. 51, No. 345: 659-668.