Table 2. Regression equations between dry weight and zinc concentration

Cultivars	Regression equations	R^2	Zn (ppm) to maximum yield
Jalo	$y=0.754999+5.050454Zn-1.009090Zn^2$	0.9279**	2.502
Mulatinho Paulista	$y=0.932499+0.697979Zn-1.959600Zn^2$	0.8987**	2.474
Ricobaio 1014	$y=1.334999+6.870706Zn-1.414141Zn^2$	0.9785**	2.429
Roxo 760	$y=1.557499+9.698686Zn-1.973737Zn^2$	0.9449**	2.456
Jamapa	$y=1.104999+8.182666Zn-1.653333Zn^2$	0.9268**	2.474
Rio Tibagi	$y=0.594999+3.485524Zn-0.710504Zn^2$	0.9559**	2.452
Tambō	$y=0.892499+6.111888Zn-1.277777Zn^2$	0.9723**	2.468
Goiano Precoce	$y=0.487499+1.919161Zn-0.383232Zn^2$	0.6796**	2.503
Porrillo Sintētico	$y=0.894999+18.990350Zn-3.807070Zn^2$	0.9721**	2.494

Plants suffering from Zn deficiency showed chlorosis in the interveinal areas of the leaf. These areas were pale green, yellow or almost white. Dry bean dry weight production was consequently drastically reduced in either Zn deficiency and Zn toxicity. The plant growth was affected more by Zn toxicity than by Zn deficiency.

In tolerance tendency was not observed among cultivars during the four-week study. For cultivars the maximum of yield was obtained in the concentration range of 2.429 to 2.503 ppm of zinc.

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EFFECT OF SILICON AND MANGANESE ON GROWTH AND NUTRIENT UPTAKE BY DRY BEAN (*Phaseolus vulgaris* L.)

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A large number of earlier published investigations demonstrated that there is a higher accumulation of mineral nutrients in aerial parts of silicon deficient plants than in aerial parts of control plants. In particular, the acummulation of manganese in dry bean plants in conditions of lowland soils of Brazil seemed to be most striking.

Silicon affects the growth of roots and shoots of some cultivated plants and dry matter yields have been greater where silicon was applied. It can be concluded that although silicon seems not to be indispensable for vegetative growth of most plants, nevertheless the indications are that it is necessary for the healthy development of many plants and may be considered to be an essential element for those plants with high silicon content.

Nine dry bean cultivars (Jalo, Mulatinho Paulista, Ricobaio 1014, Roxo 760, Jamapa, Rio Tibagi, Tambõ, Goiano Precoce, Porrillo Sintético) were grown in nutrient solution using a factorial design with 4 replications, two levels of Mn (0 and 60 ppm) and three levels of Si (0, 100 and 200 ppm). The pH was adjusted to around 4.5 - 5.5. After four weeks the plants were sampled and subjected to chemical analysis and at the same time dry matter yield, plant height and root length were recorded.

All the cultivars presented the same reaction tendency for both Si and Mn treatments and for this reason the means of all evaluations were used.

Table 1. Mean growth factors for nine dry bean cultivars

	Height (cm)	Root length (cm)	Dry weight (g)
Mn_0	40.227	40.111	0.960
Mn_0Si_{100}	26.611	22.555	0.883
Mn_0Si_{200}	23.250	15.166	0.768
$Mn_{60}Si_0$	19.027	21.694	0.483
$Mn_{60}Si_{100}$	24.083	20.138	0.968
$Mn_{60}Si_{200}$	21.166	16.083	0.548

Table 2. Silicon and manganese influence on mean mineral concentration of aerial parts of nine dry bean cultivars

	P	Mg	Mn	Si	Cu	Fe
	%		ppm			
$Mn_0\ Si_0$	0.237	1.600	108	210	17	344
$Mn_0\ Si_{100}$	0.213	1.602	66	356	17	262
$Mn_0\ Si_{200}$	0.168	1.372	54	752	14	207
$Mn_{60}Si_0$	0.153	1.242	207	202	13	375
$Mn_{60}Si_{100}$	0.186	1.636	1820	404	12	257
$Mn_{60}Si_{200}$	0.212	1.262	2076	369	15	190

The height, root length dry weight and nutrient tissue concentration were affected by both Si and Mn treatments.

In the absence of Si and the presence of Mn the plants developed a severe Mn toxicity. This toxicity was less severe when Si was present in the nutrient solution.

By applying regression analysis on dry weigh data the following general equation of dry weight yield to Si was found:

$$y = 0,483444 + 0,009383\ Si - 0,000045\ Si^2$$
$$R^2 = 0,6308^{**}$$

The general equation describes the effect of silicon on dry bean dry matter production. When 104 ppm of Si was supplied Mn toxicity was able to be controlled in the nine cultivars under study.

When Mn was not applied in the substrate increasing supply caused a decrease in P, Mg, Cu, Fe and Mn in tops, and an increase in Si content. In the presence of Mn, however, there was a decrease of P and Cu in tops; Mn and Si contents decreased when the latter was supplied at the highest concentration. Iron content was consistently reduced when Mn was supplied irrespective of the presence of Si.

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NUTRIENT ABSORPTION BY DRY BEAN (*Phaseolus vulgaris L.*) AS AFFECTED BY APPLICATION OF BORON, MOLYBDENUM AND ZINC

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Adequate nutrition of dry beans depends on several factors. Other than the ability of the soil to supply these elements, others factors include the rate of nutrient absorption, distribution of nutrient to functional sites and nutrient mobility within the plant. Interactions occur between macro and micronutrients and among all of them. Such interactions may take place in the soil as well as within the plant. Because these interactions modify the nutrition of plants, they must be understood and considered in providing an adequate micronutrient supply for normal plant growth and development.

Nine dry bean cultivars (Jalo, Mulatinho Paulista, Ricobaio 1014, Roxo 760, Jamapa, Rio Tibagi, Tambō, Goiano Precoce and Porrillo Sintético) were submitted to boron (0, 0.50 and 50 ppm), molybdenium (0, 0.01 and 1 ppm) and zinc (0, 0.05 and 5 ppm) treatments in modified Hoagland nº 2 nutrient solution to study the influence of these elements on nutrient absorption. Each treatment was obtained from three replicates and data presented here are means of these replications.