Agricultural Sciences, 2014, 5, 1037-1045
Published Online September 2014 in SciRes. http://www.scirp.org/journal/as
http://dx.doi.org/10.4236/as.2014.511112

Foliar Application of Calcium and Molybdenum in Common Bean Plants: Yield and Seed Physiological Potential

Denis Santiago Costa[1], Rafael Marani Barbosa[2], Julio Storion Oliveira[3], Marco Eustaquio Sa[4]

[1]Crop Science Department, University of Sao Paulo (USP/ESALQ), Piracicaba, Brazil
[2]Crop Science Department, Sao Paulo State University (UNESP/FCAV), Jaboticabal, Brazil
[3]BiosystemsEngineerring Department, University of Sao Paulo (USP/ESALQ), Piracicaba, Brazil
[4]Plant Science, Food Technology and Social-Economy Department, Sao Paulo State University (UNESP/FE), Ilha Solteira, Brazil
Email: denis.esalq@gmail.com

Received 7 July 2014; revised 19 August 2014; accepted 21 September 2014

Abstract

The foliar application of micro- and macronutrients is often practiced by farmers to improve yield and seed physiological potential. For calcium and molybdenum, positive results have been observed, even in soils with high nutrient content. The purpose of this study was to assess the effects of foliar applications of calcium and molybdenum on yield and seed physiological potential in common bean plants. A randomized block design was implemented, with the treatments fixed in a factorial scheme: two molybdenum rates (with or without) and four calcium rates, with four replications. The calcium rates applied on the leaves were 0, 150, 300 and 600 g·ha^{-1} for the first year of the investigation (2005) and 0, 300, 600 and 900 g·ha^{-1} for the second year (2006). In both years, the molybdenum rates applied on the leaves were 0 g·ha^{-1} (without) and 75 g·ha^{-1} (with). The results showed that the foliar calcium application, with or without molybdenum, did not improve yield. Foliar application of calcium alone improved seed physiological potential in common bean plants when applied at the full bloom stage.

Keywords

***Phaseolus vulgaris* L., Plant Nutrition, Germination, Vigor**

How to cite this paper: Costa, D.S., Barbosa, R.M., Oliveira, J.S. and Sa, M.E. (2014) Foliar Application of Calcium and Molybdenum in Common Bean Plants: Yield and Seed Physiological Potential. *Agricultural Sciences*, **5**, 1037-1045.
http://dx.doi.org/10.4236/as.2014.511112

1. Introduction

The common bean is a very important crop in Brazil because it is the main source of protein for poor people and has the advantage of being easily cultivated under different seasonal conditions. For these reasons, numerous studies have been conducted on various aspects of common bean cultivation, such as genetics [1], pathology [2] and plant nutrition [3].

The application of nutrients to the leaves (foliar application) of various crops is a practice that is now commonly used by farmers to supplement fertilizer in the soil; however, this practice is often not substantiated by research data. Thus, continued studies on the subject are justified, particularly because foliar applications are easy to implement and are relatively inexpensive, especially if foliar fertilizer sprays are combined with pesticide applications [4].

Calcium is a necessary plant nutrient that originates in igneous rocks. It is also a component of minerals such as dolomite, calcite, apatite, anorthite, and amphiboles that occur in sedimentary and metamorphic rocks. In soils of humid climates, these minerals are intemperized; additionally, part of the calcium is lost to leaching, and the rest is either adsorbed to soil colloids or trapped in biomass. Under high pH conditions, calcium can become insoluble. Plant requirements for calcium are not very high, mainly because soils that contain low levels of calcium are very acidic [5].

Some studies have demonstrated that foliar applications of calcium, either on its own or combined with other mineral nutrients, can be beneficial, increasing yield, the seed physiological potential or both, even in soil with adequate levels of this nutrient [6] [7]. Additionally, the foliar application of calcium at the full bloom stage has been justified in seed production systems because the seeds have been of higher quality than seed produced without a foliar application of calcium [8] [9].

Molybdenum is a component of two enzymes, both of which are important for nitrogen metabolism: nitrogenase, which is essential for N_2 fixing in the root system, and nitrate reductase, which is indispensable for the use of nitrates adsorbed by the common bean plant [5]. Molybdenum deficiency can be a problem because it can cause alterations in developing flowers and reduce pollen grain development [10]. It is important for plants in seed production systems to have sufficient molybdenum because the poor pollinization that is associated with molybdenum deficiency may result in lower yield due to lower fertilization rates. Some studies have shown that the yield obtained from plants that have had foliar applications of molybdenum is higher than plants that have not [11]. Since, foliar application of molybdenum has been shown to efficiently increase the seed molybdenum content; however, no improvement has been observed for seed germination and vigor [12] [13].

Seeds of good quality are a requirement for any competitive agricultural system, and thus, techniques that improve the seed yield and quality should be studied. Therefore, the purpose of the present study was to assess the relationship between foliar applications of calcium and molybdenum on common bean plants and the yield and seed physiological potential of treated plants.

2. Material and Methods

The study was carried out in Selvíria city, in Mato Grosso do Sul State, Brazil, under conventional spray irrigation conditions during the "irrigation season" (May) in 2005 and 2006 (20˚20'S; 51˚24'W). The local altitude is 335 m above sea level with a mean annual precipitation of 1370 mL, a mean annual temperature of 23˚C and a mean air relative humidity ranging from 70% to 80% yearly. The data about the weather changes during the period of the experiment is in **Figure 1**. The soil in the experimental area was classified as "TypicAcrustoxOxisol" [14], corresponding to a "LatossoloVermelhodistrófico", according to the Brazilian Soil Classification System [15]. The results of a soil chemical analysis at a depth of 0 - 0.20 m were as follows: organic matter = 10%, P_{resin} = 9 mg/L; pH ($CaCl_2$) = 5.6; K, Ca, Mg, H + Al and cation-exchange capacity = 0.2, 2.1, 1.6, 2.5 and 6.4 cmol/dm^3, respectively; bases saturation = 61%.

Seedbed preparation consisted of one plowing followed by double harrowing; the first harrowing was performed after plowing and the second harrowing before sowing, with an aim to leave the soil completely without weeds. The common bean cultivar Pérola (developed at EMBRAPA/CNPAF) was sown at 15 seeds per meter; the goal was to achieve a density of 12 seeds/m spaced with 50 cm between rows to reach a final population of 240,000 plants ha^{-1}. The plots consisted of four rows of five meters in length, with the two central rows being usable area. The sowing fertilization for all treatments consisted of 20 kg·N·ha^{-1}, 70 kg·P·ha^{-1} and 40 kg·K·ha^{-1}, applied as a commercial fertilizer (8-28-16 + Zn). As a side dressing, N was applied (at a rate of 40 kg·ha^{-1}) 25

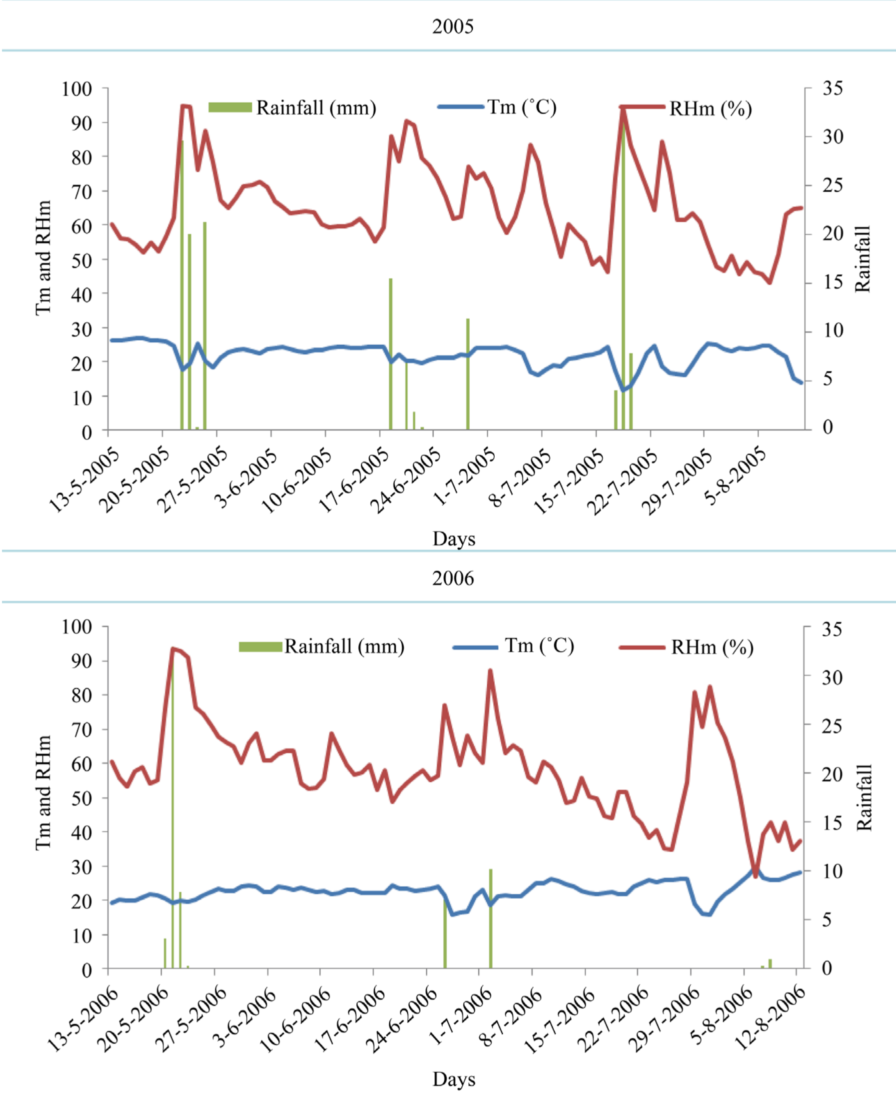


Figure 1. Weather data during the experiment in 2005 and 2006.

days after emergence, at the $V_{4\text{-}4}$ stage (*i.e.*, the first four nodes having trifoliate leaves on the main stem). Weeds were controlled by hoe at the $V_{4\text{-}3}$ stage, first three nodes on the main stem with trifoliate leaves [16]. For preventive pest control the pesticides methamidophos, triazophos + deltamethrin and chlorpyrifos were applied at 300 g a.i./ha, 262.5 + 7.5 g a.i./ha, and 480 g a.i./ha, respectively. Fungal diseases were controlled by the preventive application of mancozeb at the rate of 1600 g a.i./ha. Water was provided by conventional spray irrigation every three days or according the evapotranspiration of the area. The treatments were applied when the common bean plants reached the R_6 stage (full bloom).

A completely randomized blocks design (CRBD) was implemented, with treatments fixed in a factorial scheme: two molybdenum rates and four calcium rates, with four replications. The calcium rates applied to the leaves were 0, 150, 300 and 600 g·ha^{-1} for the first year of the investigation (2005). In 2006, the higher rates were applied (0, 300, 600 and 900 g·ha^{-1}) based on the results observed in 2005. In both years, the molybdenum rates applied to the leaves were 0 (without) and 75 g·ha^{-1}. The sources of the elements used were $CaCl_2$ for calcium and $Na_2MoO_4 \cdot 2H_2O$ for molybdenum. The spraying was performed with a backpack sprayer (20 L, piston type pump, even flat-fan nozzle 110.01, flow 100 L·ha^{-1}).

At the end of the crop cycle, 89 days in 2005 and 91 days in 2006, ten random plants were collected from each plot to assess production components: the number of pods per plant, the number of seeds per plant and the

100-weight of seeds. To determine the crop yield, the remainder of the plants was harvested, dried, manually threshed and the seeds obtained were weighed. The moisture content was determined and the weight was corrected by 13% (wet basis). The relative yield was calculated by dividing the yield of each treatment by the yield of the treatment without nutrient applications.

The seed physiological potential was assessed using a variety of methods. The seed moisture content was determined using two samples (5 g each) per treatment; each was weighed and dried in oven at 105˚C ± 3˚C for 24 h. Later, the sample dry weights were measured and the initial moisture content of each sample calculated [17]. Germination was determined using four replications of 50 seeds per treatment, sown on rolls of blotter paper. The amount of water that was used corresponded to 2.5 times the substrate weight. The samples were placed in an incubator at 25˚C ± 1˚C. The first germination count of normal seedlings occurred five days and the second count seven days after sowing [17]. After the first and second germination count, germination speed index was calculated ($\mathrm{SGI} = \frac{\text{number of normal seedlings}}{\text{days to first count}} + \cdots + \frac{\text{number of normal seedlings}}{\text{days to final count}}$) [18]. Accelerated ageing was determined using four replications of 50 seeds per treatment, distributed in a uniform layer on screens inside plastic boxes containing 40 mL of deionized water at the bottom. The boxes were covered and maintained in an incubator at 42˚C ± 1˚C for 72 h [19]. Afterward, the seeds were submitted to a germination test, and the normal seedlings were registered after five days.

For the statistical analysis, SISVAR® software was used. The data were analyzed using the F test in factorial scheme, and when F values were significant, they were further compared using the Tukey test (5%) for the molybdenum application. Finally, a regression analysis was used to determine the calcium rates.

3. Results and Discussion

Seed emergence occurred on the seventh day in 2005 and on the ninth day in 2006. The total crop cycle was 89 days in 2005 and 91 days in 2006. Emergence was delayed in 2006 because of low soil temperatures following sowing; however, this fact did not affect the total crop cycle.

In the first year, foliar application of calcium and molybdenum did not significantly affect the following parameters or their interactions: number of pods/plant, number of seeds/plant, 100-weight of seeds or yield (**Table 1**). Nevertheless, a linear tendency was noted in the higher calcium rates, promoting an increased yield on the common bean plant, observed on 600 $g \cdot ha^{-1}$. This increased yield was 4% higher when compared to the test treatment, where no rate was applied.

After considering the calcium rates from 2005, it was determined that the rates used were not enough to adjust an equation to identify the ideal calcium rate and, therefore, we increase the rates for 2006. However, the second year of results did not provide enough information to adjust the equation to describe the common bean behavior with regard to calcium rates (**Table 2**).

These results may be explained by the fact that calcium is a nutrient with low mobility in plants and foliar applications may be beneficial for correcting local deficiencies [5]. However, calcium is an element that acts as a co-factor for some proteins, aiding in signaling and the regulation of certain reactions in plants. When plants grow in unstable environments, calcium is very important because it plays a role in gene expression, improving certain cellular reactions [20]. In this study, the foliar application of calcium was expected to result in an improvement in agronomic characteristics and yield, but this was not observed.

Studies show that the foliar application of calcium is not always effective. The results obtained from this study agree with Rosolem [21], who did not detect differences in the common bean plant with regard to foliar application at the beginning bloom stage for different calcium sources and rates and in terms of yield and production components. Silva [9] did not achieve an answer to the foliar application of calcium, with and without boron when the production components and yield were assessed on the common bean plant. However, it has been observed that soybean plants are responsive to foliar applications of calcium, mainly when the application is combined with other nutrients. Bevilaqua [6] noted that there was an increase in seed weight per plant when soybeans were sprayed with calcium and boron at the full bloom stage. Souza [22] also observed higher yields when soybean plants were treated with one application of calcium and boron.

The foliar application of molybdenum did not affect yield or agronomic characteristics. When plants are cultivated with inadequate levels of this nutrient, levels of amino acids, sugars, organic acids, and purine metabolites are altered [23]. In this study, the soil molybdenum content or seed molybdenum content were enough to

Table 1. Mean values of number of pods plant^{-1} (PP), number of seeds plant^{-1} (SP), 100-seed weight (W100), yield (Y) and relative yield (RY) of common bean plants after foliar application of calcium and molybdenum, 2005.

Treatments	PP	SP	W100 (g)	Y (kg·ha^{-1})	RY (%)
			Molybdenum (g·ha^{-1})		
0	11.4 $^{n.s}$	56.5 $^{n.s}$	23.8 $^{n.s}$	2984$^{n.s}$	100
75	12.3	63.6	24.3	3024	101
LSD	1.65	7.4	0.73	303.6	-
			Calcium (g·ha^{-1})		
0	11.5$^{n.s}$	58.8$^{n.s}$	23.8$^{n.s}$	2995$^{n.s}$	100
150	11.6	60.3	23.7	3012	101
300	12.1	64.1	24.3	3050	102
600	12.4	65.7	24.4	3127	104
F values to:					
Linear regression	2.23$^{n.s}$	2.43$^{n.s}$	2.29$^{n.s}$	1.87$^{n.s}$	-
Quadratic regression	0.86$^{n.s}$	1.01$^{n.s}$	1.12$^{n.s}$	0.03$^{n.s}$	-
CV(%)	19.9	22.7	4.5	25.3	-

$^{n.s}$: No significance by F test; LSD: least significant difference; CV: coefficient of variation.

Table 2. Mean values of number of pods plant^{-1} (PP), number of seeds plant^{-1} (SP), 100-seed weight (W100) and yield (Y) of common bean plants onto foliar application of calcium and molybdenum, 2006.

Treatments	PP	SP	W100 (g)	Y (kg·ha^{-1})
		Molybdenum (g·ha^{-1})		
0	10.6$^{n.s}$	50.8$^{n.s}$	23.3$^{n.s}$	1851$^{n.s}$
75	10.6	50.1	23.6	1884
LSD	1.77	8.56	0.87	381.47
		Calcium (g·ha^{-1})		
0	10.0$^{n.s}$	48.2$^{n.s}$	23.6$^{n.s}$	1799$^{n.s}$
300	10.4	48.9	23.5	1910
600	11.9	57.2	23.2	1935
900	10.1	47.4	23.0	1827
F values to:				
Linear regression	1.27$^{n.s}$	0.97$^{n.s}$	2.21$^{n.s}$	1.54$^{n.s}$
Quadratic regression	2.49$^{n.s}$	3.48$^{n.s}$	1.23$^{n.s}$	2.43$^{n.s}$
CV (%)	23.0	23.3	4.9	28.0

$^{n.s}$: No significance by F test; LSD: least significant difference; CV: coefficient of variation.

maintain the plants metabolism and therefore did not affect the results.

For the foliar application of molybdenum, studies have shown divergences, sometimes favorable, other times not so. Barbosa [24] studied the effects of the application of molybdenum and nitrogen on the common bean and determined that after excluding the effect of nitrogen, molybdenum did not increase the yield or production components. In contrast, Nascimento [25] found that the foliar application of molybdenum interacted with low rates of nitrogen to improve yield, but when the N rates were increased, this effect disappeared. Additionally, Ascoli [26] observed an increase in seed production when common bean plants were treated with a foliar application of molybdenum. In general, the foliar application of calcium, with or without molybdenum, does not increase the production components or yield of the common bean.

With regard to the seed physiological potential, differences in the foliar application of calcium and molybdenum were not observed on the germination and vigor during the 2005 study year (**Table 3**). However, different rates of calcium did result in differences in the first germination count and the speed germination index (**Table 4**, **Figure 2**), with ideal rates of calcium estimated at 300 g·ha^{-1} for the speed germination index and 325 g·ha^{-1} for the first germination count.

Some studies have demonstrated an improvement in seed physiological potential after the foliar application of calcium because, in addition to its other functions, this element is responsible for the formation of calcium pectate, which is present in plant cell walls [5]. For this reason, plants that are sprayed at an appropriate stage with ideal rates of calcium may have a more structured membrane system, reducing the leaching of ions, which results in seeds with more vigor [7]. Rosolem [21] also observed an improvement in germination speed as a function of the rate of calcium applied to the common bean plant, agreeing with the present study.

Table 3. Mean values of moisture content (MC), germination (G), first germination count(FGC), accelerated aging (AA) and germination speed index (GSI) of common bean seeds after foliar application of calcium and molybdenum, 2005.

Treatments	MC	G	FGC	AA	GSI
	(%)				-
		Molybdenum (g·ha^{-1})			
0	10.7	97$^{n.s}$	92$^{n.s}$	95$^{n.s}$	9.5$^{n.s}$
75	10.7	96	92	94	9.4
LSD	-	2.37	3.47	2.02	2.95
		Calcium (g·ha^{-1})			
0	10.8	94$^{n.s}$	88$^{n.s}$	96$^{n.s}$	9.1$^{n.s}$
150	10.7	98	95	96	9.7
300	10.7	97	91	93	9.4
600	10.6	97	94	94	9.6
F values to:					
Linear regression	-	0.43$^{n.s}$	0.63$^{n.s}$	2.34$^{n.s}$	1.02$^{n.s}$
Quadratic regression	-	2.11$^{n.s}$	4.02$^{n.s}$	0.43$^{n.s}$	3.14$^{n.s}$
CV (%)	-	3.2	5.3	3.0	3.9

$^{n.s}$: No significance by F test; LSD: least significant difference; CV: coefficient of variation.

Table 4. Mean values of moisture content (MC), germination (G), first germination count(FGC), accelerated aging (AA) and germination speed index (GSI) of common bean seeds after foliar application of calcium and molybdenum, 2006.

Treatments	MC	G	FCG	AA	GSI
	(%)				-
		Molybdenum (g·ha^{-1})			
0	11.2	93$^{n.s}$	88$^{n.s}$	89$^{n.s}$	9.2$^{n.s}$
75	11.1	92	86	89	9.0
LSD	-	3.14	3.33	2.47	3.07
		Calcium (g·ha^{-1})			
0	10.9	89$^{n.s}$	83*	86$^{n.s}$	8.8*
300	11.2	91	85	85	9.1
600	11.4	92	85	89	8.9
900	11.1	89	81	84	8.6
F values to:					
Linear regression	-	0.97$^{n.s}$	2.43$^{n.s}$	0.46$^{n.s}$	1.96$^{n.s}$
Quadratic regression	-	3.01$^{n.s}$	12.41*	0.53$^{n.s}$	10.58*
CV (%)	-	4.0	6.2	3.9	3.0

$^{n.s}$: No significance by F test; LSD: least significant difference; CV: coefficient of variation.

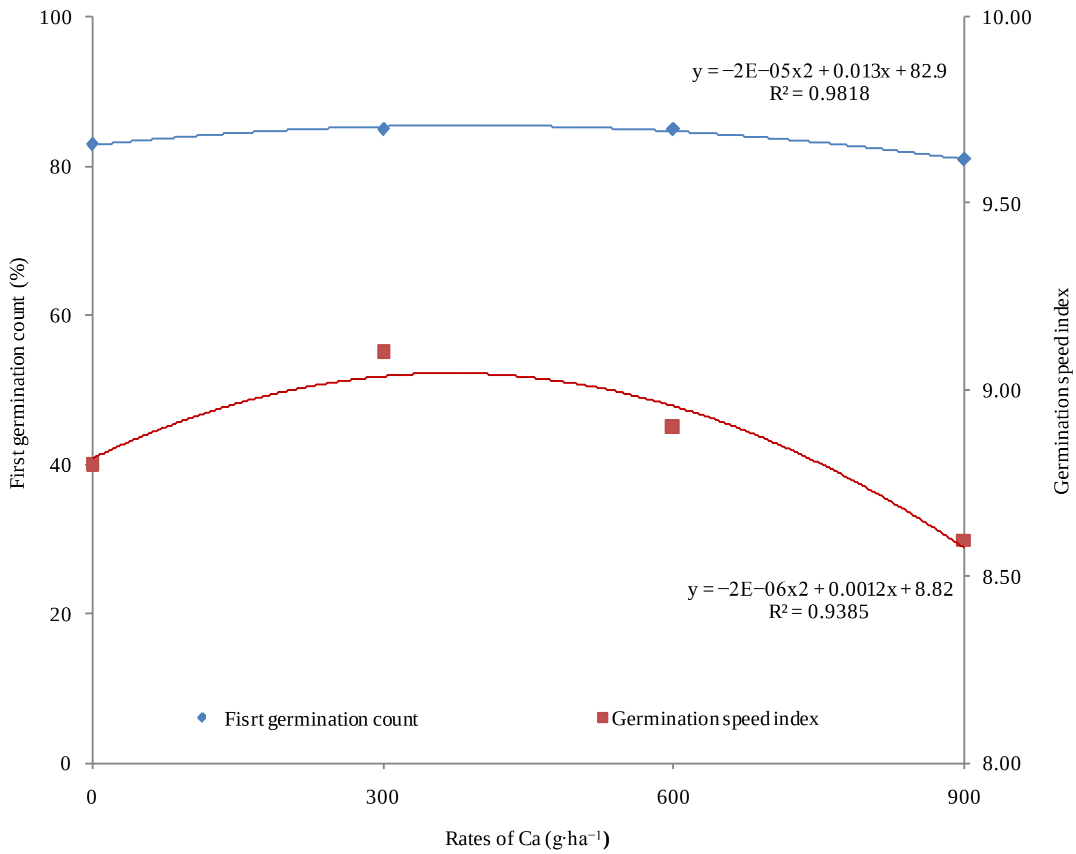


Figure 2. First count of germination and germination speed index for different rates of foliar application of calcium, 2006.

Foliar application of molybdenum did not improve seed physiological potential because the amount of this nutrient which is necessary to physiological process is not so much and probably the molybdenum content already in the seed was enough. This is in agreement with studies performed by Bassan [27] which also found no alteration of seed physiological potential after the foliar application of molybdenum to common bean plants.

4. Conclusion

The foliar calcium application, with or without molybdenum, did not improve yield. Foliar application of calcium alone improved seed physiological potential in common bean plants when applied at the full bloom stage.

Acknowledgements

We thank "field team" at UNESP/FE for their valuable contribution during the development of the project and for taking care of the irrigation system.

References

[1] Oliveira, G.V., Carneiro, P.C.S., Carneiro, J.E.S. and Cruz, C.D. (2006) A daptabilidade e estabilidade de linhagens de feijão comum em Minas Gerais [Adaptability and Stability of common bean in Minas Gerais State, Brazil]. *Pesquisa Agropecuária Brasileira*,**41**, 257-265. http://dx.doi.org/10.1590/S0100-204X2006000200010

[2] Garcia, A., Souza, P.E., Pozza, E.A. and Santos, F.S. (2007) Influênciadas variáveis ambientais noprogresso da antracnose do feijoeiro e eficiência de tiofanato metílico + clorotalonil no controle da doença [Influence of the Environmental Variables in the Progress of Anthracnose of Bean and Efficiency of Thiophanate Methyl + Chlorothalonil in the Control of the Disease]. *Ciência e Agrotecnologia*, **31**, 1709-1715. http://dx.doi.org/10.1590/S1413-70542007000600016

[3] Afonso, R.J., Arf, O., Costa, D.S., Barbosa, R.M., Buzetti, S., Sá, M.E. and Rodrigues, R.A.F. (2011) Combinações de fontes de nitrogênio no desenvolvimento e rendimento do feijoeiro [Combination of Nitrogen Sources on Common Bean Growth and Yield]. *Pesquisa Agropecuária Tropical*, **41**, 391-398. http://dx.doi.org/10.5216/pat.v41i3.12360

[4] Evangelista, J.R.E., Oliveira, J.A., Botelho, F.J.E., Carvalho, B.O., Vilela, F.L. and Oliveira, G.E. (2010) Qualidade fisiológica e produtividade de sementes de feijão oriundas de sementes tratadas com enraizante e nutrição mineral das plantas [Physiological Quality and Yield of Bean Seeds from the Seeds Treated with Rooter and Mineral Nutrition Plants]. *Ciência e Agrotecnologia*, **34**, 1664-1668. http://dx.doi.org/10.1590/S1413-70542010000700013

[5] Malavolta, E. (2006) Manual de nutrição mineral de plantas [Manual of Plant Mineral Nutrition]. Agronômica Ceres, São Paulo.

[6] Bevilaqua, G.A.P., Silva-Filho, P.M. and Possenti, J.C. (2002) Aplicação foliar de cálcio e boro e componentes de rendimento e qualidade de sementes de soja [Boron and Calcium Leaf Application and Yield Components and Physiological Quality of Soybean Seeds]. *Ciência Rural*, **32**, 31-34. http://dx.doi.org/10.1590/S0103-84782002000100006

[7] Farinelli, R., Penariol F.G., Souza, F.S., Piedade, A.R. and Lemos, L.B. (2006) Características agronômicas e qualidade fisiológica de sementes de cultivares de feijão adubados via foliar com cálcio e boro [Agronomic Characteristics and Seed Physiological Quality of Common Bean Cultivars Fertilized by Foliar Application of Calcium and Boron]. *Científica*, **34**, 59-65. http://www.cientifica.org.br/index.php/cientifica/article/view/30

[8] Harter, F.S. andBarros, A.C.S.A. (2011) Cálcio e silícionaprodução e qualidade de sementes de soja [Calcium and Silicon on Production and Quality of Soybean Seeds]. *Revista Brasileira de Sementes*, **33**, 54-60. http://dx.doi.org/10.1590/S0101-31222011000100006

[9] Silva, T.R.B., Soratto, R.P., Bíscaro, T. and Lemos, L.B. (2006) Aplicação foliar de boro e cálcio no feijoeiro [Boron and Calcium Foliar Application on Common Bean]. *Científica*, **34**, 46-52. http://www.cientifica.org.br/index.php/cientifica/article/view/28

[10] Agarwala, S.C., Sharma, C.P., Farooq, S. and Chatterjee, C. (1978) Effect of Molybdenum Deficiency on the Growth and Metabolism of Corn Plants Raised in Sand Culture. *Canadian Journal of Botany*, **56**, 1905-1909. http://dx.doi.org/10.1139/b78-227

[11] da Silva, M.V., Andrade, M.J.B., Moraes, A.R. and Alves, V.G. (2003) Fontes e doses de molibdênio via foliar em duas cultivares de feijoeiro [Molybdenum Sources and Rates Applied on Leaves of Two Common Bean Cultivars]. *Ciência e Agrotecnologia*, **27**, 126-133. http://dx.doi.org/10.1590/S1413-70542003000100015

[12] Possenti, J.C. and Villela, F.A. (2010) Efeito do molibdênio aplicado via foliar e via sementes sobre o potencial fisiológico e produtividade de sementes de soja [The Effect of Molybdenum Applied by Foliar Spraying and Seed Treatment on the Physiological Potential and Productivity of Soybean Seeds]. *Revista Brasileira de Sementes*, **32**, 143-150. http://dx.doi.org/10.1590/S0101-31222010000400016

[13] Silva, A.C., Costa, D.S., Barbosa, R.M. and Lazarini, E. (2012) Cobalto e molibdênio via foliar em amendoim: Características agronômicas da produção e potencial fisiológico das sementes [Foliar Fertilization of Peanuts with Cobalt and Molybdenum: Agronomic Characteristics of Production and Physiological Potential of Seeds]. *Biotemas*, **25**, 9-15. http://dx.doi.org/10.5007/2175-7925.2012v25n2p9

[14] Soil Survey Staff (2010) Keys to Soil Taxonomy. 11th Edition, USDA, Washington DC.

[15] Embrapa (2006) Sistema Brasileiro de Classificação de Solos [Brazilian Soil Classification System]. Embrapa Produção da Informação&Embrapa Solos Brasília, Rio de Janeiro.

[16] Costa, D.S., Barbosa, R.M. and de Sá, M.E. (2013) Weed Management and Its Relation to Yield and Seed Physiological Potential in Common Bean Cultivars. *Pesquisa Agropecuária Tropical*, **43**, 147-154. http://dx.doi.org/10.1590/S1983-40632013000200010

[17] Brasil (2009) Regras para análise de sementes [Rules for Seed Testing]. Ministério da Agricultura, Pecuária e Abastecimento/Secretaria de Defesa Agropecuária, Brasília.

[18] Maguire, J.D. (1962) Speed of Germination—Aid in Selection and Evaluation for Seedling Emergence and Vigor. *Crop Science*, **2**, 176-177. http://dx.doi.org/10.2135/cropsci1962.0011183X000200020033x

[19] Hampton, J.M. and Tekrony, D.M. (1995) Handbook of Vigour Test Methods. 3rd Edition, ISTA, Zürich.

[20] Kim, M.C., Chung, W.S., Yun, D.J. and Cho, M.J. (2009) Calcium and Calmodulin-Mediated Regulation of Gene Expression in Plants. *Molecular Plant*, **2**, 13-21. http://dx.doi.org/10.1093/mp/ssn091

[21] Rosolem, C.A., Boaretto, A.E. and Nakagawa, J. (1990) Adubação foliar do feijoeiro: VIII. Fontes e doses de calico [Foliar Aplication in Common Bean: VIII. Sources and Rates of Calcium]. *Científica*, **18**, 81-86.

[22] Souza, L.C.D., Sá, M.E., Carvalho, M.A.C. and Simidu, H.M. (2008) Produtividade de quatro cultivares de soja em função da aplicação de fertilizante mineral foliar a base de cálcio e boro [Soybean Seeds Yield of Four Cultivars as Function of the Leaf Mineral Fertilizer Application of Calcium and Boron]. *Revista de Biologia e Ciência da Terra*, **8**,

37-44.

[23] Ide, Y., Kusano, M., Oikawa, A., Fukushima, A., Tomatsu, H., Saito, K., Hirai, M.Y. and Fujiwara, T. (2011) Effects of Molybdenum Deficiency and Defects in Molybdate Transporter MOT1 on Transcript Accumulation and Nitrogen Sulphur Metabolism in *Arabidopsis thaliana*. *Journal of Experimental Botany*, **62**, 1483-1497. http://dx.doi.org/10.1093/jxb/erq345

[24] Barbosa, G.F., Arf, O., Nascimento, M.S., Buzetti, S. and Freddi, O.S. (2010) Nitrogênio em cobertura e molibdênio foliar no feijoeiro de inverno [Side Dressing Nitrogen and Leaf Molybdenum in the Winter Common Bean Plant]. *Acta Scientiarum*, *Agronomy*, **32**, 117-123. http://dx.doi.org/10.4025/actasciagron.v32i1.1605

[25] Nascimento, M.S., Arf, O., Barbosa, G.F., Buzetti, S., Nascimento, R.S. and Castro, R.M. (2009) [Nitrogênio em cobertura e molibdênio via foliar em feijoeiro de inverno no sistema plantio direto II: Características agronômicas e produtividade [Side Dressing Nitrogen and Leaf Molybdenum Application on Winter Common Bean Crop under No Tillage System II: Agronomic Characteristics and Yield]. *Scientia Agraria*, **10**, 351-358. http://www.redalyc.org/articulo.oa?id=99512493002

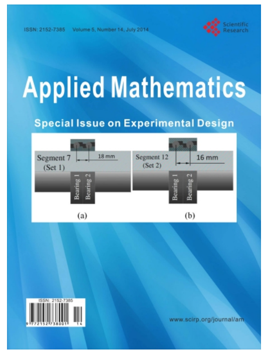
[26] Ascoli, A.A., Soratto, R.P. and Maruyama, W.I. (2008) Aplicação foliar de molibdênio, produtividade e qualidade fisiológica de sementes de feijoeiro irrigado [Molybdenum Leaf Application, Yield and Physiologic Quality of Irrigated Common Bean Seeds]. *Bragantia*, **67**, 377-384. http://dx.doi.org/10.1590/S0006-87052008000200013

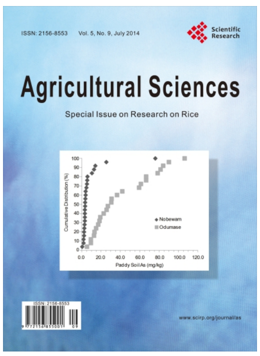
[27] Bassan, D.A.Z., Arf, O., Buzetti, S., Carvalho, M.A.C., Santos, N.C.B. and Sá, M.E. (2001) Inoculação de sementes e aplicação de nitrogênio e molibdênio na cultura do feijão de inverno: Produção e qualidade fisiológica de sementes [Seed Inoculation, Nitrogen and Molybdenum Applicationon a Winter Bean Crop: Production and Physiological Seed Quality]. *Revista Brasileira de Sementes*, **23**, 76-83.

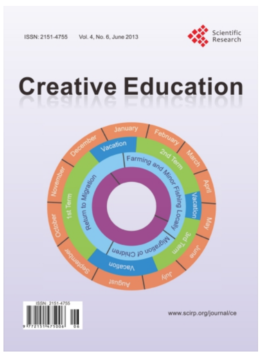

Advances in
Bioscience and Biotechnology

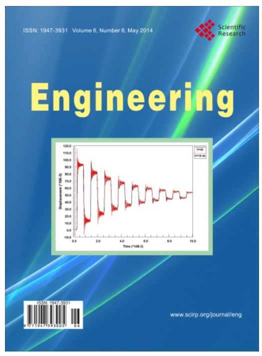

American Journal of
Analytical Chemistry


American Journal of
Plant Sciences
Special Issue on Photosynthesis

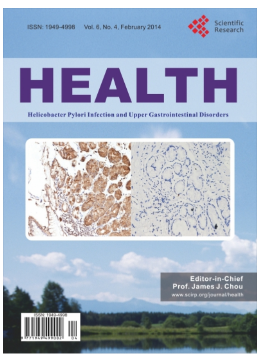

Applied Mathematics
Special Issue on Experimental Design

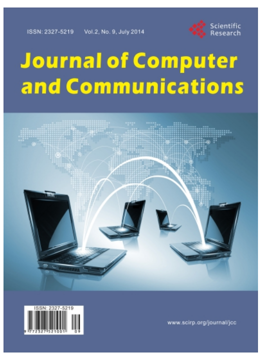

Agricultural Sciences
Special Issue on Research on Rice


Creative Education

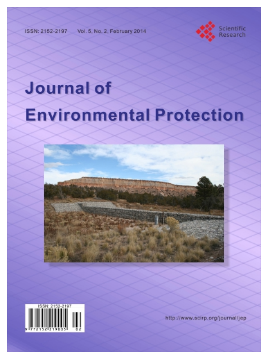

Engineering

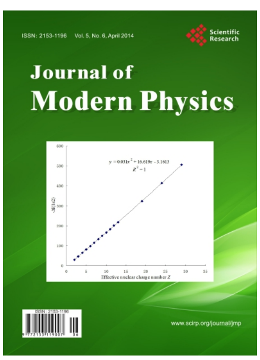

Food and Nutrition Sciences

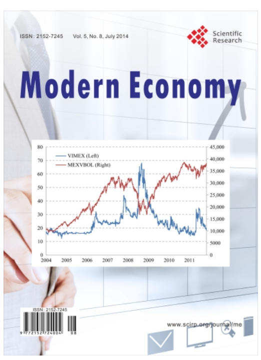

HEALTH
Helicobacter Pylori Infection and Upper Gastrointestinal Disorders
Editor-in-Chief
Prof. James J. Chou

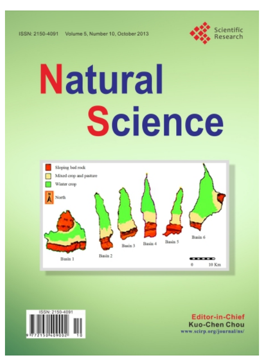

Journal of Computer
and Communications

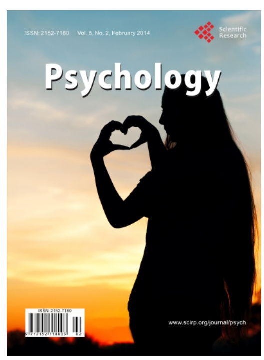

Journal of Cancer Therapy
Special Issue on Bone Tumor Research


Journal of
Environmental Protection


Journal of
Modern Physics


Modern Economy


Natural
Science
Editor-in-Chief
Kuo-Chen Chou


Psychology