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INFLUENCE OF $CaCO_3$ WORDINGS BY NP DOSES ON SOYBEAN YIELDS

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Abstract

Following recent research, the positive influence of calcium on soybean plants, especially on varieties with improved genetic qualities, was found. The results obtained on the plants were significant both on the total biomass of the plants and its components. In our ecological conditions with stagnant white luvic soil (pH = 5.0-5.5) different types of $CaCO_3$ were used to primarily improve the chemistry of the plant culture medium. In the case of the variety Isa TD (group 00), the interaction between $CaCO_3$ and NP fertilizers contributed to a maximum increase of 5.48 t/ha total biomass, 3.44 t/ha pod biomass and 1.47 t/ha of biomass grains. Of the two factors, the new formulations of $CaCO_3$ had the greatest influence, and the interaction with NP was in all cases negative. The correlations obtained between the studied characters were significantly positive, except for the mass of one thousand grains (MTG). The obtained results invite the promotion of soybean crop technology, including the amendment system regarding this type of soil.

Key words: *acid soils, biomass, Ca^{2+}, Isa TD, NP.*

INTRODUCTION

Soybean [*Glycine max*. (L) Merrill, pro syn. *G. angustifolia* Miq., *G. gracilis* Skvort., *G. hispida* (Moench) Maxim] is one of the most important oil plants worldwide (Corke & Wrigley, 2004). Being considered one of the most important sources of vegetable protein, for the prevention and combating of malnutrition, it is aimed to increase the production of soybean crop by up to 2.4%, until the year 2050 (Cramer et al., 2009; Martinez-Ballesta et al., 2010). The plant offers several major advantages in sustainable cropping systems including the ability to fix atmospheric nitrogen (N_2) and therefore mitigate the need to apply large amounts of nitrogen fertilizers. Due to the fact that it is part of the category of leguminous plants, soybean contributes to improving the level of soil fertility (Martinez-Ballesta et al., 2010). The Isa TD soybean variety belongs to the early maturity group (00), has an erect habit, compact bush, determined growth, gray pubescence, purple flowers and gray hilum color. In the first year of cultivation, the morphological characteristics of the variety were as follows: waist 71 cm, number of branches 3-4, number of pods 70, number of grains 111, and mass of one thousand grains (MTG) 180-220 g. The vegetation period was 161 days.

Calcium (Ca) is an essential macronutrient for plants, having the role of improving soil properties and various physiological processes in plants (White & Broadley, 2003; Hepler & Winship, 2010). The amounts of Ca present in the stagnant white luvic soil are insufficient for plant growth. Therefore, it does not show enough potential to maintain the right degrees of base saturation of the soil colloids. In these conditions, the exchangeable aluminum ions Al^{3+} dominate the exchange sites of the clay, contributing to the excessive acidity of the soil. Mobile (soluble) aluminum becomes toxic to the most of plants. Due to the lack of calcium and the excess presence of aluminum, the soil becomes strongly acidic, an environment in which plant development is reduced, which leads to the impairment of production (Milivojevic & Stojanovic, 2003). By applying $CaCO_3$, the following properties are improved: structure, permeability to water and air, development of microorganisms and intake as fertilizer in plant food. Calcium absorbed as Ca^{2+} ions is an essential element for fruit growth and development. The resistance of plants to diseases is also of particular importance (Villegas-Torres et al., 2007) due to the way in which the cell wall is protected.

The roles of Ca in plants are as follows:
- helps the growth and development of plants;
- confers resistance to diseases by protecting the cell wall;
- activation of some enzyme systems;
- stabilizes the membrane and cell integrity (White & Broadley, 2003).

Ca^{2+} is absorbed from the soil solution by the root system and translocated to the shoots through the xylem. The root must balance calcium input to the xylem (White, 2001) to help individual root cells use $[Ca^{2+}]_{cyt}$ for intracellular signaling. At the level of growth tips and leaves, where photosynthesis takes place, Ca activates either alone or together with Mg^{2+} and other chemical elements, such as: Ca, $n.10^{-1}$ in the form of Ca^{2+}; Mg, $n.10^{2}$, in the form of Mg^{2+} and Mg ATP^{2-}; K, 1.6, as K^{+}; Na, $n.10^{-2}$, in the form of Na^{+}; Cl, $n.10^{-2}$, in the form of Cl^{-}. Due to this fact, the leaves of soybean plants have an intense green color. The way calcium enters the plant (Cosgrove, 2005; Franceschi & Nakata, 2005) is passive with the flow of water and other nutrients. Its circulation through woody vessels is favored by plant evapotranspiration (ETP) and root pressure (Holdaway-Clarke & Heppler, 2003; Dayod et al., 2010). Being a macroelement totally different from the others, the permanent application of Ca ions is necessary. In this sense, different formulations of calcium carbonate were used, with or without the addition of magnesium. As a result of the research carried out, the very good effect of the application of amendments and doses of chemical fertilizers was found.

MATERIALS AND METHODS

The experience took place during the year 2022 and was located in the experimental field of the Fertilizer Laboratory, from S.C.D.A. Soybean variety Isa TD (00) was cultivated in non-irrigated culture. The placement was done in a subdivided plot with 3 repetitions each, and the biological material was sown mechanically, in rows 10 m long, 3 m wide, so that each variant had a size of 30 m². Between the rows the distance was 50 cm. The experience is bifactorial and has the following graduations:

-Factor A: -a_1: unamended (0 t/ha);
- a_2: Agrocalcium powder (2.5 t/ha), 93.6% $CaCO_3$;
- a_3: Doloflor powder (2.5 t/ha), 58.87% $CaCO_3$ and 38.24% MgO;
- a_4: Doloflor granules (2.5 t/ha), 58.87% $CaCO_3$ and 38.24% MgO;
- a_5: Neutrosol 9 powder (2.5 t/ha), 97.5% $CaCO_3$;

-Factor B: - b_1: unfertilized;
- b_2: $N_{40}P_{40}$;
- b_3: $N_{80}P_{80}$.

Table 1. The proper soil characteristics

Soil characteristics	Stagnic white luvic soil	
	Values	Interpretation
Humus, %	2.26	low fertility
Total nitrogen-tN, %	0.130	poorly supplied
P_2O_5, ppm	41.68	poorly supplied
K_2O, ppm	89.00	medium supplied
pH	5.12	high acidity

The technology used was the one recommended by the station. The soil in which the experimental field was located is a stagnant white luvic soil, acid, with a low humus content, being a weakly fertile soil, little supplied with nitrogen, phosphorus and moderately supplied with potassium, in accessible forms to the plants (Table 1). Variants harvesting were done manually with the metric frame in all 3 repetitions. The samples were kept for several days in the laboratory at room temperature to bring them to the same humidity required for the determinations. Soybean samples were analyzed for: total biomass, pod biomass, grain biomass and mass of 1000 grains (MTG). The obtained data were processed statistically by the variance analysis method (anova test) and by studying the correlations expressed by excel graphs. Correlations included the correlation coefficient of determination (D%) and correlation coefficient (r) values. The obtained values were compared with the transgression probabilities for the thresholds of 5%, 1% and 0.1%.

RESULTS AND DISCUSSIONS

The influence of climatic factors on soybean products. From a climatic point of view, A.R.D.S. Pitesti is located in an area with a specific climate. Temperatures and precipitations were recorded from May to September 2022 to track their influence on soybean plants. The climatic conditions during the experiment period (Table 2) were differentiated both in terms of temperatures, but especially in the amount of precipitation recorded from one month to another. During the first period of vegetation, the temperatures were close to normal, after which, during the summer, the recorded values were 2-3ºC higher.

The temperatures exceeded the multiannual values recorded by 1.4ºC compared to normal (N) one. During the soybean vegetation period, 1538.8ºC was accumulated, active temperatures (Σtn >10ºC).

Regarding the precipitation regime, it was found that the values in May, July and September were close to normal.

Table 2. Evolution of climatic factors in soybean vegetation

Month	Temperatures, tn^0C				Precipitations, mm			ETP**
	N*	2022	±	$\Sigma tn^0 > 10^0C$	N*	2022	±	mm
May	16.3	17.1	0.8	1538.8	81	77	-4	33
Jun.	19.5	21.6	2.1		94	14	-80	74
Jul.	21.7	23.8	2.1		81	71	-10	141
Aug.	21.3	23.7	2.4		60	105	45	176
Sep.	16.9	16.5	-0.4	Veg. Per.	53	46	-7	66
±	19.14	20.54	1.4	138 zile	369	313	-56	490

Although 56 mm less was recorded, nevertheless the volume of rains that fell mostly covered the needs of the plants. In the month of June, the precipitation was well below the normal limit, and in the month of August, the amount of precipitation recorded exceeded the normal by 45 mm. The additional rains in the second summer month led to the extension of the vegetation period of the plants. Making a comparison between the plant's need at an optimal level expressed by potential evapotranspiration (ETP) and the climatic factors recorded in the Isa TD variety, a deficit of it is found at a sufficiently high level.

Soybean productions obtained within the experiment. Regarding the variants without chemical fertilizers (Table 3), the productions obtained according to the new calcium formulations were between 3.51 t/ha in the control variant and 7.67 t/ha on the Neutrosol 9 amendment.

Table 3. The total soybean biomass formation (t/ha)

Ca/NP	$N_0 P_0$	$N_{40} P_{40}$	$N_{80} P_{80}$	Factors influnce
Check	3.51	4.43	5.59	Maximum growth, 5.48 t/ha, 100%
A-Ca powder	4.29	5.14	8.10	
D-Ca powder	6.37	4.56	6.62	Ca 4.16 t/ha, 76%
D-Ca granule	6.31	8.99	7.06	
N-Ca powder	7.67	7.24	5.70	NP 2.08 t/ha, 37%
	Ca	*NP*	*Ca x NP*	
DL 5 % = *DL 1 % =* *DL 0.1 %=*	*1.03* *1.49* *2.24*	*1.60* *2.19* *2.96*	*3.45* *4.76* *6.56*	Ca x NP -0.76 t/ha, -13%

In the same conditions, in the variants that were fertilized with $N_{40}P_{40}$, the productions obtained were between 4.43 t/ha and 7.24 t/ha, and in the variant with $N_{80}P_{80}$, the levels were between 5.59 t/ha and 5.70 t/ha.

Considering the influences of the 2 factors, the maximum increase in biomass obtained was 5.48 t/ha (100%). Ca contributed to this with 4.16 t/ha (76%), and NP chemical fertilizers brought an extra 2.08 t/ha (37%). Analyzing the interaction between the 2 factors, a negative increase of 0.76 t/ha (-13%) is found.

The causes of the negative interaction of total soybean biomass was due to a possible antagonistic interaction between cations (Table 3).

Table 4. The total pod biomass formation (t/ha)

Ca/NP	N_0 P_0	N_{40} P_{40}	N_{80} P_{80}	Factors influnce
Check	2.55	2.82	3.66	Maximum growth, 3.44 t/ha, 100%
A-Ca powder	2.90	3.37	5.21	
D-Ca powder	4.38	3.16	4.51	Ca 2.87 t/ha, 83%
D-Ca granule	4.43	5.99	4.62	
N-Ca powder	5.42	4.81	3.72	NP 1.11 t/ha, 32%
	Ca	*NP*	*Ca x NP*	
DL 5 % = *DL 1 % =* *DL 0.1 %=*	*1.01* *1.47* *2.21*	*0.66* *0.89* *1.21*	*0.91* *1.28* *1.84*	Ca x NP -0.54 t/ha, -15%

Taking into account the non-chemically fertilized variants (Table 4), the pod productions obtained according to the new calcium formulations were between 2.55 t/ha in the control variant and 5.42 t/ha on the agrofund with Neutrosol 9. In the variants which were fertilized with $N_{40}P_{40}$, the obtained yields were between 2.82 t/ha and 4.81 t/ha. In the same way, the productions obtained in the variants fertilized with $N_{80}P_{80}$, the yields were between 3.66 t/ha and 3.72 t/ha. The maximum increase obtained was 3.44 t/ha (100%), and Ca contributes with 2.87 t/ha (83%), and NP with 1.11 t/ha (32%). If we analyze the interaction between the 2 factors, there is also a negative increase of 0.54 t/ha (-15%). It is possible that this negative range is due to the same relative antagonism between calcium and phosphorus.

Table 5. The soybean grain biomass formation (t/ha)

Ca/NP	N_0 P_0	N_{40} P_{40}	N_{80} P_{80}	Factors influence
Check	1.23	1.25	1.53	Maximum growth, 1.47 t/ha, 100%
A-Ca powder	1.17	1.79	2.79	
D-Ca powder	2.10	1.47	2.13	Ca 1.41 t/ha, 96%
D-Ca granule	2.22	2.64	2.12	
N-Ca powder	2.58	2.20	1.73	NP 0.30 t/ha, 20%
	Ca	*NP*	*Ca x NP*	
DL 5 % = *DL 1 % =* *DL 0.1 %=*	*0.47* *0.68* *1.02*	*0.29* *0.39* *0.53*	*0.41* *0.56* *0.76*	Ca x NP -0.24 t/ha, -16%

The grain yields obtained in the non-chemically fertilized variants (Table 5), were between 1.23 t/ha in the control variant and 2.58 t/ha in the variant fertilized with Neutrosol 9. In the variants where fertilizers of the type were administered $N_{40}P_{40}$ and different types of amendments, the obtained productions were between 1.25 t/ha and 2.20 t/ha. The productions obtained in the variants fertilized with $N_{80}P_{80}$, depending on the new calcium formulations, were between 1.53 t/ha in the control variant and 2.79 t/ha in the variant fertilized with agrocalcium powder. The maximum increase resulted was 1.47 t/ha, Ca contributing 1.41 t/ha, and the NP fertilizer dose 0.30 t/ha, and in this case their interaction is negative: -0.24 t/ha.

In the case of the mass of one thousand grains (MTG) the interaction between the two factors was insignificantly positive at the level of 1 g (3%) (table 6). Under the same conditions, the MTG was between 185 and 216 g, resulting in a maximum increase of 31 g (100%). Calcium contributed 19 g (61%), and NP chemical fertilizer with 11 g (36%) (Table 6).

Table 6. Mass formation of a thousand grains - MTG (g)

Ca/NP	N_0 P_0	N_{40} P_{40}	N_{80} P_{80}	Factors influnce
Check	203	209	214	Maximum growth,
A-Ca powder	196	201	206	31 g, 100%
D-Ca powder	204	196	212	Ca
D-Ca granule	196	216	206	19 g, 61%
N-Ca powder	185	199	211	NP
	Ca	*NP*	*Ca x NP*	11 g, 36%
DL 5 % = *DL 1 % =* *DL 0.1 %=*	*15* *23* *34*	*15* *21* *28*	*27* *37* *52*	Ca x NP 1 g, 3%

Table 7. Scatter analysis of soybean yield formation

Cause of variability	Sq. total				LG	Variance, S^2				F test			
	d.w.	pods	grains	MTG		d.w.	pods	grains	MTG	d.w.	pods	grains	MTG
Rep.	4.80	2.31	0.55	907	2								
A Fact.	45.66	21.73	5.11	579	4	11.41	5.43	1.276	144.7	12.8*	6.26*	6.94*	0.70
A Er.	7.12	6.94	1.47	1648	8	0.89	0.868	0.184	206.0				
Big Fact.	57.58	30.98	7.13	3134	12								
B Fact.	7.31	1.36	0.382	1241	2	3.65	0.68	0.191	620.7	1.37	1.53	0.022	2.56
A x B	48.78	21.70	6.137	1015	8	6.10	2.71	0.767	126.9	2.30	6.09*	0.090	0.52
B Er.	53.14	8.90	170.5	4846	20	2.66	0.445	8.526	242.3				
Small Fact.	109.2	31.96	117.1	7102	30								
Total	166.8	62.94	184.2	10236	44								

In the case of A factor, through the dispersion analysis of the data (Table 7), it emerges that the differences are significantly positive in all determinations (total biomass, pod biomass and grain biomass). In the case of factor B, differences are recorded, but without significance, and in the case of interactions between the two factors, significant positive differences are recorded only in the case of pod biomass. The following figures (Figures 1-4) show images of the soybean crop, both in full vegetation and as a grain appearance.

Figure 2. The period of formation of pods

Figure 1. The variety Isa at the beginning of flowering

Figure 3. The Isa TD variety towards maturity

Figure 4. The grains of the Isa TD variety

The correlations between the production elements (biomass) are highly significant positive which means that the variety Isa TD expressed high values in the experiment (Table 8).
Among the two types of correlations, the determination values were between 67% and 98% regarding plant biomass and between 0.1% and 4.2% in the case of the mass of one thousand grains (MTG).

Table 8. Correlations between the main determinations of soybean plants, variety Isa

Indices	Total d.w.	Pod number	Pod d.w.	Grain number	Grain d.w.	MTG
Total d.w.	1	84.6* **.920****	98.1 **.970**	83.4 **.913**	90.8 **.953**	1.68 .130
Pod number		1	82.8 **.910**	66.3 **.814**	71.1 **.844**	2.39 .155
Pod d.w.			1	88.3 **.940**	92.2 **.960**	0.20 .045
Grain number				1	95.0 **.975**	**4.16 -.204**
Grain d.w.					1	0.10 -.032
MTG						1
	DL 5%= .190, DL 1%= .250, DL 0.1%= .320					

*Correlation coefficient of determination (D%), **correlation coefficient (r)

The obtained data demonstrate that this variety showed characteristics with a certain high degree of adaptability in the conditions at the station.
Correlations were obtained from the mean values from each repetition. The correlation between the number of grains and the number of pods is highly significant positive (Figure 5).
With regard to the technological elements used, the plant manages to produce as large a number of pods as possible and to the same extent a higher number of grains was formed.
The correlation between the number of grains and the MTG is significantly negative (Figure 6), which demonstrates that at a higher number of grains, the MTG keeps its relative uniformity even if it can decrease. This phenomenon is due to the existence of a genetic factor that is not very easily changed from a technological point of view.
From the analysis of the obtained data of the 4 types of biomass, new and valuable aspects of the Isa TD soybean variety are found (Table 9).
Considering the interaction between the two experimental factors, the total biomass varied between 3.51 t/ha in the control and 8.99 t/ha in the variant with doloflor granules + $N_{40}P_{40}$.

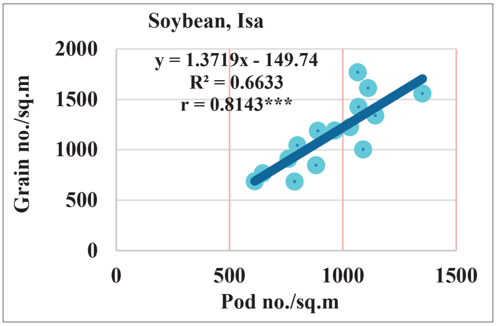

Figure 5. Correlation between pod no. x grain no./sq.m

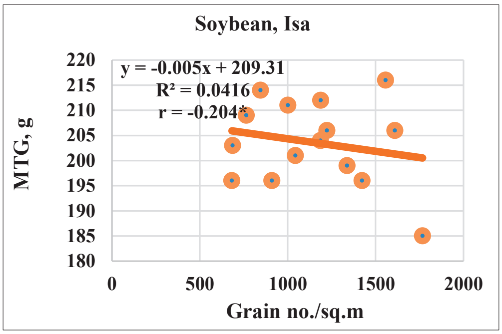

Figure 6. Correlation between grain no./sq.m x MTG

Very significant positive values were found in the variants with: agrocalcium powder + $N_{80}P_{80}$; doloflor granules + $N_{40}P_{40}$; doloflor granules + $N_{80}P_{80}$; neutrosol powder; neutrosol powder + $N_{40}P_{40}$. The pod biomass formed was between 2.55 t/ha in the control version and 5.99 t/ha in the version with doloflor granules + $N_{40}P_{40}$. On average, the biomass of the grains was 1.93 t/ha. Thus, from a percentage point of view, at the level of the whole experiment, the pods represented 67.22%, the grains 31.59%, and in the case of the MTG, the statistical difference was insignificant.

Table 9. Biomass structure of soybean plants, variety Isa TD, depending on the experimental factors

$CaCO_3$	NP	TOTAL d.w. t/ha	Pod d.w. t/ha	%/ total	Grain d.w. t/ha	%/ total	MTG g
0	N_0 P_0	3.51	2.55	72.65	1.23	35.04	203
	N_{40} P_{40}	4.43	2.82	80.06	1.25	28.22	209
	N_{80} P_{80}	5.59	**3.66**	65.47	1.53	27.37	214
A-Ca pw	N_0 P_0	4.29	2.90	67.60	1.17	27.27	196
	N_{40} P_{40}	5.14	3.37	65.56	**1.79**	34.82	201
	N_{80} P_{80}	**8.10**	**5.21**	64.32	**2.79**	34.44	206
D-Ca pw	N_0 P_0	6.37	**4.38**	68.76	**2.10**	32.97	204
	N_{40} P_{40}	4.56	3.16	69.30	1.47	32.24	196
	N_{80} P_{80}	6.62	**4.51**	68.13	**2.13**	32.18	212
D-Ca gr	N_0 P_0	6.31	**4.43**	70.21	**2.22**	35.18	196
	N_{40} P_{40}	**8.99**	**5.99**	66.63	**2.62**	29.14	216
	N_{80} P_{80}	**7.06**	**4.62**	65.44	**2.12**	30.03	206
N-Ca pw	N_0 P_0	**7.67**	**5.32**	70.66	**2.58**	33.64	185
	N_{40} P_{40}	**7.24**	**4.81**	66.44	**2.20**	30.39	199
	N_{80} P_{80}	5.70	**3.72**	65.26	**1.73**	30.35	211
	MEAN	6.10	4.10	67.22	1.93	31.59	203.60
DL 5 %		3.454	0.909		0.409		26.7
DL 1 %		4.759	1.282		0.557		37.1
DL 0.1%		6.558	1.837		0.756		52.1

CONCLUSIONS

1. The experiment consisted in improving soil acidity by promoting new formulations with different but high percentages of calcium. At the 3 agrofunds of chemical fertilizers of the NP type: 0 kg/ha, 40 kg/ha and 80 kg/ha per amendment fund, both a development of the root system and of the plant biomass was found.
2. The total biomass of the Isa TD soybean plant was 5.48 t/ha to which calcium contributed 76% and NP fertilizer 37%. Regarding pod biomass, the maximum increase was 3.44 t/ha, with the influence of Ca being 83% and NP 32%. In the case of grain biomass, a maximum increase of 1.47 t/ha was recorded, with Ca contributing 96% and NP 20%.
3. The causes of the negative interaction of the two factors, in all three determinations, was due to a possible interaction between the cations.
4. At the mean level, the MTG was 203.6 g with no significance due to the fact that this trait is genetically controlled and therefore less variable.
5. Through the dispersion analysis, significant aspects were demonstrated, which invites the promotion of new soybean varieties under the amendment conditions. The correlation obtained between the production elements: the number of pods/m^2 and the number of grains/m^2, the values show positive and significant links.
6. From the results obtained this year, the Isa TD variety reacted very favorably due to the improvement of both soil and plant physiology in the calcium element.

REFERENCES

Corke, W. and Wrigley, H. (2004). *Encyclopedia of Grain Science*. Academic Press. ISBN 978-0-12-765490-4.

Cosgrove, D.J. (2005). Growth of the plant cell wall. *Nature Reviews, Molecular Cell Biology, 6*. 850–861.

Cramer, M.D., Hawkins, H.J., Verboom, G.A. (2009). The importance of nutritional regulation of plant water flux. *Oecologia, 161*. 15–24.

Dayod, M., Tyerman, S.D., Leigh, R.A., Gilliham, M. (2010). Calcium storage in plants and the implications for calcium biofortification. *Protoplasma, 247*. 215– 231.

Franceschi, V.R., Nakata, P.A. (2005). Calcium oxalate in plants: formation and function. *Annual Review of Plant Biology, 56*. 41–71.

Hepler, P.K., Winship, L.J., (2010). Calcium at the cell wall-cytoplast interface. *Journal of Integrative Plant Biology, 52*. 147–160.

Holdaway-Clarke, T.L. & Heppler, P.K. (2003). Control of pollen tube growth: role in ion gradients and fluxes, New Phytologist, 159. 539–563.

Martinez-Ballesta, M.C., Dominguez-Perles, R., Moreno, D.A., Muries, B., Alcaraz-Lopez, C., Bastias, E., Garcia-Viguera, C., Carvajal, M. (2010). Minerals in plant food: effect of agricultural practices and role in human health. A review. *Agronomy for Sustainable Development, 30*. 295– 309.

Milivojevic, D. & Stojanovic, D. (2003). Role of calcium in aluminium toxicity on content of pigments and pigment= protein complexes of soybean. *Journal Plant Nutrition, 26*(2). 341–350.

Villegas-Torres, O.G., Alia, I.T., Acosta C.M.D., Guillén, D.S., Lopez, V.M. (2007). Relationship between calcium and crop diseases. *Agricultural Research, 4*(1), 77–86.

White, P.J. (2001). The pathways of calcium movement to the xylem. *Journal of Experimental Botany, 52*. 891– 899.

White, P.J. & Broadley, M.R. (2003). Calcium in plants. *Annals of Botany, 92*. 487–511.