MODEL OF PHYSIOLOGICAL INDICES VARIATION IN MAIZE UNDER SILICON INFLUENCE

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***Abstract**. The study analyzed the variation of some physiological indexes of maize leaves, the Lovrin 400 hybrid, under the influence of silicon treatments (0, 0.1 ml l^{-1}, 1.0 ml l^{-1}, 1.5 ml l^{-1} 2.5 ml l^{-1}). Silicon has favorably influenced the dimensional parameters of the leaves (L, w, LA, Chl, Tl,Sw). There were very high and high correlations between Si and L (r=0.935), Si and Tl (r=0.856),and low correlations between Si and Sw (r=0.687), Si and LA (r=0.675), Si and Chl (r=0.528), respectively Si and L (r=0.500). Linear and polynomial equations of order 2 and 3 facilitated the estimation of the physiological indexes studied on the basis of Si concentration, under statistical safety.The LA variation according to L and w was described by grade 3 polynomial models (LA according to L: R^2= 0.897, p<<0.001, F=76.089; LA according to w: R^2= 0.812, p<<0.001, F=37.384).*

***Key words**: leaf area, maize, models, physiological indices, silicon*

INTRODUCTION

Silicon is a nutrient that plays an important role in plant nutrition, especially plant health and increased stress tolerance, as well as the quantity and quality of the yields [48, 13, 44, 6]. The literature has highlighted the importance of silicon in plant nutrition, the contribution and benefits of Si for crop plants, or spontaneous flora.

It has been observed the favorable influence of silicon on plant growth and development [1], increasing salinity tolerance [2, 45], thermal stress tolerance [21], water and osmotic stress[15, 50, 24],increasing plant tolerance to aluminum[7, 12, 10, 11], increasing the resistance of plants to certain pathogens[22, 31], increasing the availability of nutrients for plants [25]ș.a.

Liu et al. (2009) [23] have reported the silica intake in enzymatic activity with antioxidant role in the cucumber.An important role of Si in the photosynthesis and in gene expression of rice in high stress conditions of Zn was recorded and reported by Song et al. (2014) [46].

In corn, the favorable contribution of Si was found to the photosynthesis process, in the content of chlorophyll, stomatal conductance, intercellular CO_2 concentration, transpiration rate and photosynthetic rate [49]. Sacała (2017) [39] recorded the favorable influence of Si on the content of chlorophyll and some physiological and biochemical indices on maize plants under saline stress conditions. Amin et al. (2018) [5] reported favorable results of Si treatment on plant physiological indices, and productivity elements in corn cob, under moisture stress conditions.

The present study evaluated the influence of silicon on some physiological indexes in maize leaves, under field conditions.

MATERIALS AND METHODS

The biological material was represented by the Lovrin 400 hybrid, which was fertilized with N at 40 kg a.s. ha^{-1}. Silicon was applied as silicic acid in concentrations of: 0, 0.5, 1.0, 1.5 and 2.0 ml l^{-1}. Three treatments were applied at 4 leaves, 6-8 leaves and 10 leaves, Principal growth stage I: Leaf development BBCH Code [27].

Dimensional parameters of the leaves were evaluated (length - L, widt - w) by measuring with precision of ±0.5 mm. The leaf area (LA) was determined based on the model proposed by Sala et al. (2015) [42], relation (1).

$$LA = L \cdot w \cdot K_A \quad (1)$$

where: LA – leaf area; L – leaf length; w – leaf width; K_A – constant of the surface or correction factor (0.77).

Chlorophyll content (Chl) was determined with a Chlorophyll Meter, SPAD 502 Plus (Konica Minolta), with a precision of ±0.2 SPAD units. The thickness of the leaf (Tl) was determined by measuring by electronic caliper, with an accuracy of ± 0.001 mm.The specific weight (Sw) was determined by calculation based on the weight of a known area, determined with an Axis balance (ATS 60), with a working accuracy of ± 0.001g.

The experimental data were analyzed by the ANOVA test, correlation analysis, and regression analysis.Mathematical models represented by linear and polynomial equations of order 2 and 3 were obtained to describe the change in physiological indices according to the concentration of Si. The safety of the results was confirmed by the statistic parameters r, R^2, p, F. For the data processing the PAST software was used [16].

RESEARCH RESULTS

Silicon, applied in gradually increasing concentrations, within the limit of 0 - 2 ml 1^{-1}, determined the specific variation of some physiological indices in maize.

The variation in leaf sizes parameters (L, w), leaf area (LA), leaf thickness (T1), chlorophyll content (Chl) and specific leaf weight (Sw), were evaluated.The results obtained are presented in Table 1.

Leaf length varied in relation to the Si concentration applied between 69.36 ± 1.51 cm in the control variant and 77.42 ± 1.61 cm in variant V3.

The leaf width had values between 9.26 ± 0.14 cm for variant V0 and 10 ± 0.13 cm for variants V3 and V4.Based on the leaf sizes and the correction factor of 0.77, leaf area (LA) was calculated according to the model proposed by Sala et al. (2015).

Foliar surface values ranged from 495.15 ± 15.96 cm^2 in the control variant and 596.79 ± 16.91 cm^2 at V3.It was found that although the average width was equal to variants V3 and V4, the leaf length was the foliar parameter that differentiated the foliar surface.

Foliar thickness (Tl) had values between 0.204 ± 0.007 mm for control variant (V0) and 0.228 ± 0.003 mm for variant V3.The chlorophyll content oscillated between 28.18 ± 0.53 SPAD units at control variant (V0) and 32.60 ± 1.33 SPAD units at V2 variant.

The specific weight on the foliar surface unit (Sw) ranged between 0.0058 ± 0.0002 g in control variant (V0) and 0.0064 ± 0.0001 g in variant V2.

Table 1.

Experimental data for foliar physiological indices in maize, in relation to silicon

Varianta	Si (ml/l)	L (cm)	w (cm)	LA (cm^2)	Tl (mm)	Chl (SPAD units)	Sw (g/cm^2)
V0(Control)	0.00	69.36±1.51	9.26±0.14	495.15±15.96	0.204±0.007	28.18±0.53	0.0058±0.0002
V1	0.50	73.10±1.77	9.60±0.14	562.67±21.23	0.206±0.002	30.42±0.85	0.0061±0.0002
V2	1.00	76.88±1.94	9.88±0.17	569.45±22.59	0.208±0.002	32.60±1.33	0.0064±0.0001
V3	1.50	77.42±1.61	10.02±0.13	596.79±16.91	0.228±0.003	32.06±1.12	0.0063±0.0001
V4	2.00	72.48±1.56	10.00±0.13	557.88±12.52	0.222±0.002	30.26±1.64	0.0062±0.0001

The ANOVA single factor test revealed the presence of variance in the experimental data set (Ntotal = 179), based on the experimentally controlled factor, silicon doses, F>Fcrit, p << 0.001, for Alpha = 0.001, Table 2.

The statistical correlation analysis highlighted the existence of positive correlations of variable level, between silicon (Si) as a control factor and physiology indexes studied, Table 3.

Table 2.

ANOVA Single factor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6745158	5	1349032	1678.825	3.5E-145	3.959003
Within Groups	139818.9	174	803.5571			
Total	6884977	179				

Alpha = 0.001

Very high correlations are observed between Si and w (r=0.935), high correlations between Si and T1 (r=0.856),and lower level correlations between Si and LA, L, Chl,ans respectively Sw. Very high correlations between L and LA (r = 0.906), L and Chl (r = 0.980), L and Sw (r = 0.922) and respectively between Sw and Chl (r = 0.904) have been identified at the level of physiological indices.

High correlations were recorded between LA and w (r = 0.867), between LA and Chl (r = 0.891), Sw and w (r = 0.893) and between Sw and LA (r = 0.886) respectively.Mean level correlations were found between L and w (r = 0.767), T1 and w (r = 0.794) and respectively Chl and w (r = 0.793), and low level correlations were found between LA and Tl (r = 0.662) as well as among the other physiological indices studied.

Table 3.

Matrix correlation table

	Si	L	w	LA	Chl	Tl	Sw
Si		0.39051	0.019798	0.21155	0.36078	0.064221	0.20023
L	0.500		0.1299	0.034286	0.003277	0.38914	0.0257
W	0.935	0.767		0.057153	0.10919	0.10899	0.041135
LA	0.675	0.906	0.867		0.042444	0.22339	0.045301
Chl	0.528	0.980	0.793	0.891		0.477	0.006135
Tl	0.856	0.502	0.794	0.662	0.424		0.39249
Sw	0.687	0.922	0.893	0.886	0.970	0.499	

Starting from the high correlation between Si treatments and the physiological indexes at the foliar level studied, mathematical models for assessing the behavior of physiological indices according to the Si concentration applied were searched for.

The positive variation of the values of the physiological indices under the influence of the Si treatments highlights the contribution of the silicon, as a nutritional element with specific role, to metabolic processes, highlighted at the level of some physiological indexes studied [43].

The favorable intake of microelements administered to seeds or foliage was highlighted in different cultures in terms of physiological indices [33, 34, 35], productivity elements and production quality [18].

The variation of the physiological indexes studied, depending on the treatments applied within the limits of 0-2 ml l^{-1}, was described by the linear and polynomial equations of orders 2 and 3, in safe conditions, Table 4.Particular distributions of values for the variance of LA and Chl indices according to Si concentration are shown in Figures 1 and 2.

Relationships of interdependence have also been identified in the physiological indexes studied.

Table 4.

Equations and statistical safety parameters for the change of physiological indices under Si influence

Factor of influence	Physiologic index	Equation	Eq no.	Statistically safe parameters		
				p	R^2	F
Si	L	$L = -3.68x^3 + 5.154x^2 + 5.971x + 69.35$	(2)	0.02371	0.998	960.21
	w	$w = -0.24x^2 + 0.856x + 9.252$	(3)	0.00158	0.998	631.00
	LA	$LA = -54.95x^2 + 141.8x + 497$	(4)	0.07273	0.927	12.754
	Chl	$Chl = -3.086x^2 + 7.331x + 28$	(5)	0.03195	0.968	30.261
	T	$T = 0.0116x + 0.202$	(6)	0.06421	0.733	8.2182
	Sw	$Sw = -0.0003429x^2 + 0.0008857x + 0.005789$	(7)	0.04313	0.957	22.188

x – Si concentration in solution

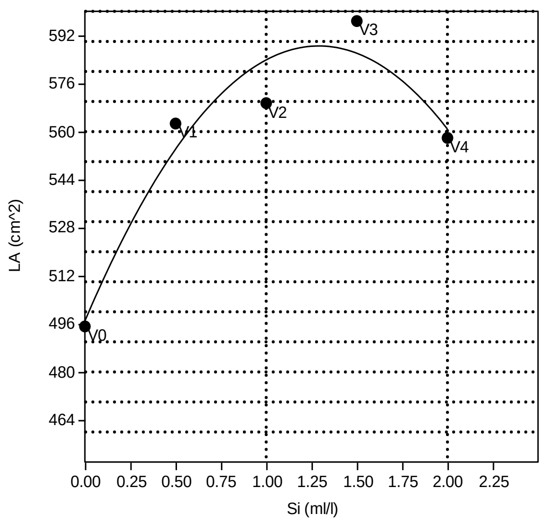

Figure 1. Graphical distribution of LA values according to Si concentration

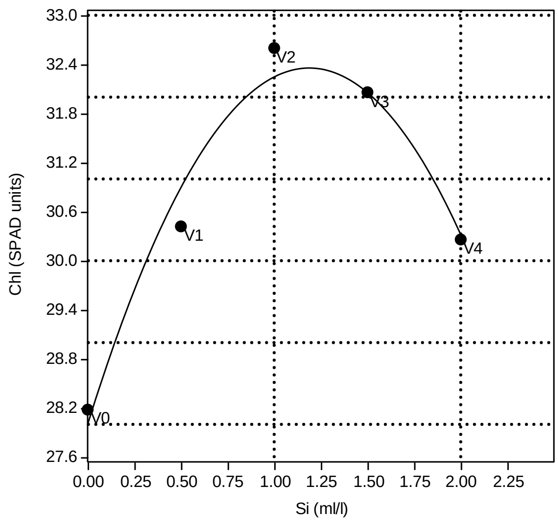

Figure 2.Graphical distribution of Chl values according to Si concentration

Polynomial models of order 3 described, in a safe statistical way, the interdependence between LA and L (R^2 = 0.897, p << 0.001, F = 76.089) relation (8), respectively between LA and w (R^2 = 0.812, <0.001, F = 37.384) the relationship (9).The graphical distributions of LA values according to L and w respectively are presented in Figures 3 and 4.

$$LA = 0.0168x^3 - 3.75x^2 + 288.9x - 7089 \quad (8)$$

where: x - leaf length (L)

$$LA = -31.28x^3 + 874.7x^2 - 8017x + 2.458E04 \quad (9)$$

where: x - leaf width (w)

Maize is a crop that responds well to fertilization, and in this sense, a number of studies have communicated models of response and prediction on the variation of some biometric parameters, physiological indices, productivity elements, quantity and quality in production [9, 17]. Models using polynomial functions can be used to determine the local or global optimal values of the studied phenomenon [38, 41].

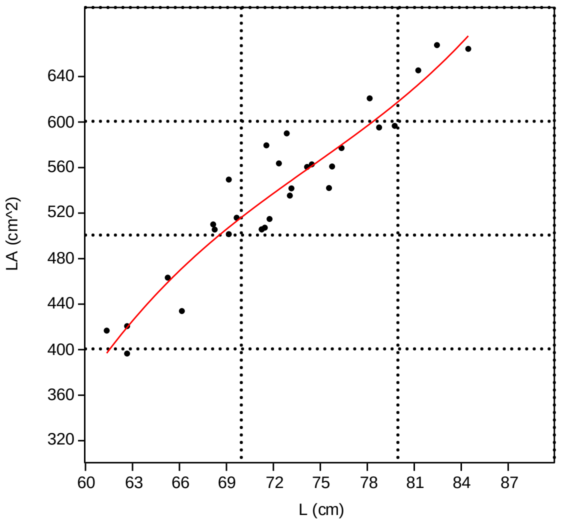

Figure 3.The graphical distribution of LA values, according to L

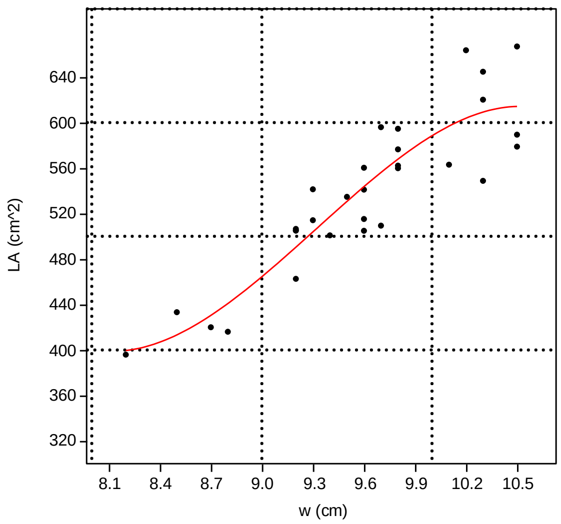

Figure 4.The graphical distribution of LA values, depending on w

The differential contribution of foliar parameters L and w to leaf area (LA) was also highlighted in other studies [42, 40].Also, mathematical models of foliar surface estimation based on parameters L and w were obtained and in other research, in statistical and safety conditions[8, 28, 37].

The positive influence of Si on some physiological indices (foliar surface, chlorophyll content), on increasing the tolerance to thermal stress, hydric and saline of plants, on metabolic processes, as well as on the elements of productivity was found in wheat [4, 30, 26], sunflower [47], rice [19], maize [29, 14, 20, 5, 32], sorghum [3], tomatoes [36].

The results obtained in the present study are in line with the tendency of the results communicated by other authors, and confirm the favorable influence of Si within the limits of the tested concentrations on the physiological indexes studied in maize.

CONCLUSIONS

Silicon, foliar application as silicic acid, to the Lovrin 400 maize hybrid has favorably influenced leaf physiological indices such as leaf area (LA), chlorophyll content (Chl), leaf thickness (Tl), and respectively the specific weight (Sw).

Models represented by linear and polynomial equations were obtained to describe the variation of physiological indices in relation to the Si concentration in the tested range (0-2 ml $^{-1}$).

The foliar surface variation was described by grade 3 polynomial models in relation to biometric leaf parameters, L and w, under the influence of Si treatments.

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REFERENCES

[1]. ADATIA, M.H., & BESFORD, R.T., 1986, The effects of silicon on cucumber plants grown in recirculating nutrient solution. Annals of Botany, 58, 343-351.
[2]. AHMAD, R., ZAHEER, S.H., & ISMAIL, S., 1992, Role in silicon in salt tolerance of wheat (*Triticumaestivum* L.). Plant Science, 85, 43-50.
[3]. AHMED, M., HASSEN, F., QADEER, U., & ASLAM, M.A., 2011, Silicon application and drought tolerance mechanism of sorghum. African Journal of Agricultural Research, 6(3), 594-607
[4]. AKRAM, H.M., SATTAR, A., ALI, A., & NADEEM, M.A., 2010, Agro-physiological performance of wheat genotypes under moisture stress conditions. Journal of Agricultural Research, 48(3), 361-368.
[5]. AMIN, M., AHMAD, R., ALI, A., HUSSAIN, I., MAHMOOD, R., ASLAM, M., & LEE, D.J., 2018, Influence of silicon fertilization on maize performance under limited water supply. Silicon, 10(2), 177-183.
[6]. ARTYSZAK, A., 2018, Effect of silicon fertilization on crop yield quantity and quality-A literature review in Europe. Plants, 7, 54.
[7]. BARCELÓ, J., GUEVARA, P. & POSCHENRIEDER, C., 1993, Silicon amelioration of aluminium toxicity in teosinte (*Zea mays* L. ssp. mexicana). Plant and Soil, 154, 249-255.
[8]. BLANCO, F.F., FOLEGATTI, M.V., 2003, A new method for estimating the leaf area index of cucumber and tomato plants.HorticulturaBrasileira, 21(4), 666-669.
[9]. BOLDEA, M., SALA, F., RAWASHDEH, H., & LUCHIAN, D., 2015, Evaluation of agricultural yield in relation to the doses of mineral fertilizers. Journal of Central European Agriculture, 16(2), 149-161.
[10]. COCKER, K.M., EVANS, D.E. & HODSON, M.J., 1998a, The amelioration of aluminium toxicity by silicon in higher plants: Solution chemistry or an in planta mechanism? PhysiologiaPlantarum, 104, 608-614.
[11]. COCKER, K.M., EVANS, D.E., & HODSON, M.J., 1998b. The amelioration of aluminium toxicity by silicon in wheat (*Triticumaestivum* L.) - malate exudation as evidence for an in planta mechanism. Planta, 204, 318-323.
[12]. CORRALES, I., POSCHENRIEDER, C., & BARCELÓ, J., 1997, Influence of silicon pretreatment on aluminium toxicity in maize roots. Plant Soil, 190, 203-209.
[13]. GUNTZER, F., KELLER, C., & MEUNIER, J.D., 2011, Benefits of plant Si for crops: a review. Agronomy for Sustainable Development, 32, 201-213.
[14]. HABIBI, G., 2016, Effect of foliar-applied silicon on photochemistry, antioxidant capacity and growth in maize plants subjected to chilling stress. ActaagriculturaeSlovenica, 107(1): 33-43.
[15]. HABIBI, G., & HAJIBOLAND, R., 2013, Alleviation of drought stress by Si supplementation in maize (*Pistaciavera* L.) plants. Folia Horticulturae, 25: 21-29.
[16]. HAMMER, Ø., HARPER, D.A.T., & RYAN, P.D., 2001, PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 1-9.
[17]. HERBEI, M., & SALA, F., 2016, Biomass prediction model in maize based on satellite images.AIP Conference Proceedings 1738: 350009-1 – 350009-4.
[18]. JIVAN, C., & SALA, F., 2014, Relationship between tree nutritional status and apple quality. Horticultural Science, 41(1):1-9.

[19]. KIM, Y-H., KHAN, A.L, SHINWARI, Z.K., KIM, D-H., WAQAS, M., KAMRAN, M., & LEE, I-J., 2012, Silicon treatment to rice (*Oryza sativa* L. cv.'Gopumbyeo') plants during different growth periods and its effects on growth and grain yield. Pakistan Journal of Botany, 44(3), 891-897.

[20]. LATEF, A.A.A., & TRAN, L.-S.P., 2016, Impacts of priming with silicon on the growth and tolerance of maize plants to alkaline stress.Frontiers in Plant Science.7: 243.

[21]. LIANG, Y., ZHUC, J., LI, Z., CHUA, G., DINGC, Y., ZHANGC, J., & SUN, W., 2008, Role of Si in enhancing resistance to freezing stress in two contrasting winter wheat cultivars. Environmental and Experimental Botany, 64(3), 286-294.

[22]. LIANG, Y.C., SUN, W.C., SI, J., & ROMHELD, V., 2005, Effects of foliar-and root-applied silicon on the enhancement of induced resistance to powdery mildew in *Cucumissativus*. Plant Pathology, 54, 678-685.

[23]. LIU, J., LIN, S., XU, P., WANG, X., & BAI, J.. 2009, Effects of exogenous silicon on the activities of antioxidant enzymes and lipid peroxidation in chilling-stressed cucumber leaves. Agricultural Sciences in China, 8: 1075-1086.

[24]. LIU, P., YIN, L., DENG, X., WANG, S., TANAKA, K., & ZHANG, S., 2014. Aquaporin-mediated increase in root hydraulic conductance is involved in Si induced improved root water uptake under osmotic stress in *Sorghum bicolor* L. Journal of Experimental Botany, 65(17), 4747- 4756.

[25]. MA, J.F., & TAKAHASHI, E., 2001, Chapter 2 Silicon as a beneficial element for crop plants. Studies in Plant Science, 8, 17-39.

[26]. MAGHSOUDI, K., EMAM, Y., & ASHRAF, M., 2016, Foliar application of silicon at different growth stages alters growth and yield of selected wheat cultivars. Journal of Plant Nutrition 39(8), 1194-1203.

[27]. MAIER, U., 2001, Growth stages of mono- and dicotyledonous plants – BBCH Monograph, 2nd Edition, Federal Biological Research Centre for Agriculture and Forestry, Braunschweig, Germany, 158 p.

[28]. MOKHTARPOUR, H., THE, C.B.S., SALEH, G., SELAMAT, A.B., ASADI, M.E., & KAMKAR, B., 2010, Non-destructive estimation of maize leaf area fresh weight, and dry weightusing leaf length and leaf width. CBCS 5(1), 19-26.

[29]. MOUSSA, H.R., 2006, Influence of exogenous application of silicon on physiological response of salt-stressed maize (*Zea mays* L.). International Journal of Agriculture & Biology, 8(3), 293-297

[30]. PEI, Z., MING, D., LIU, D., WAN, G., GENG, X., GONG, H., & ZHOU, W., 2010, Silicon improves the tolerance to water-deficit stress induced by polyethylene glycol in wheat (*Triticumaestivum* L.) seedlings. Journal of Plant Growth Regulation, 29(1), 106-115

[31]. POZO, J., URRESTARAZU, M., MORALES, I., SÁNCHEZ, J., SANTOS, M., & DIANEZ, F., 2015, Effects of silicon in the nutrient solution for three horticultural plant families on the vegetative growth, cuticle, and protection against *Botrytis cinerea*.Hortscience, 50(10), 1447-1452.

[32]. PUPPE, D., & SOMMER, M., 2018, Experiments, uptake mechanisms, and functioning of silicon foliar fertilization - A review focusing on maize, rice, and wheat. Advances in Agronomy, 152, 1-49.

[33]. RAWASHDEH, H.M., & SALA, F., 2013, The effect of foliar application of iron and boron on early growth parameters of wheat (*Triticumaestivum* L.). Research Journal of Agricultural Science, 45(1), 21-26.

[34]. RAWASHDEH, H.M., & SALA, F., 2015, Foliar application with iron as A vital factor of wheat crop growth, yield quantity and quality: A Review. International Journal of Agricultural Policy and Research, 3(9), 368-376.

[35]. RAWASHDEH, H., & SALA, F., 2016, The effect of iron and boron foliar fertilization on yield and yield components of wheat. Romanian Agricultural Research, 33, 1-9.

[36]. ROMERO-ARANDA, M.R., JURADO, O., &CUARTERO., J., 2006, Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. Journal of Plant Physiology, 163(8), 847-855.

[37]. ROUPHAEL, Y., MOUNEIMNE, A.H., ISMAIL, A., MENDOZA-DE GYVES, E., RIVERA, C.M., & COLLA, G., 2010, Modeling individual leaf area of rose (*Rosa hybrida* L.) based onleaf length and width measurement. Photosynthetica, 48 (1), 9-15.

[38]. RUJESCU, C.I., MATEIA, A.N., MARTIN, S., & CIOLAC, R., 2015, Determination of the optimum productions surface (monofactorial model) having an initial fixed capital. Quaestus, (7), 149.

[39]. SACAŁA, E., 2017, The influence of increasing doses of silicon on maize seedlings grown under salt stress. Journal of Plant Nutrition, 40(6), 819-827.

[40]. SALA, F., IORDĂNESCU, O., & DOBREI, A., 2017, Fractal analysis as a tool for pomology studies: case study in apple. AgroLife Scientific Journal, 6(1), 224-233.

[41]. SALA, F., RUJESCU, C., & CONSTANTINESCU, C., 2016, Causes and solutions for the remediation of the poor allocation of P and K to wheat crops in Romania.AgroLife Scientific Journal, 5(1), 184-193.

[42]. SALA, F., ARSENE, G.-G., IORDĂNESCU, O., BOLDEA, M., 2015, Leaf area constant model in optimizing foliar area measurement in plants: A case study in apple tree. Scientia Horticulturae, 193, 218-224.

[43]. SALA, F., 2011, Agrochimie. Ed. Eurobit, Timisoara, pp. 29-44.

[44]. SAHEBI, M., HANAFI, M.M., AKMAR, A.S.N., RAFII, M.Y., AZIZI, P., TENGOUA, F.F., AZWA, J.N.M., & SHABANIMOFRAD, M., 2015, Importance of silicon and mechanisms of biosilica formation in plants.BioMedical Research International, 2015, 396010.

[45]. SAQIB, M., ZÖRB, C., & SCHUBERT, S., 2008, Si-mediated improvement in the salt resistance of wheat (*Triticumaestivum*) results from increased sodium exclusion and resistance to oxidative stress. Functional Plant Biology, 35, 633-639.

[46]. SONG, A., LI, P., FAN, F., LI, Z., & LIANG, Y., 2014, The effect of silicon on photosynthesis and expression of its relevant genes in rice (*Oryza sativa* L.) under high-zinc stress.PLoS ONE, 9(11), e113782.

[47]. TAHIR, M., AHMAD, S., AYUB, M., NAEEM, M., & SARWAR, M., 2013, Impact of planting time and silicon levels on yield and yield components of sunflower (*Helianthus annuus* L.). Pakistan Journal of Life and Social Sciences (Pakistan), 11(1), 60-64

[48]. WIESE, H., NIKOLIC, M., & RÖMHELD, V., 2007, Silicon in plant nutrition.in: Sattelmacher B., Horst W.J. (eds) The apoplast of higher plants: Compartment of storage, transport and reactions. Springer, Dordrecht.

[49]. XIE, Z., SONG, F., XU, H., SHAO, H., & SONG, R., 2014, Effects of silicon on photosynthetic characteristics of maize (*Zea mays* L.) on alluvial soil.Scientific World Journal, 2014, 718716.

[50]. YIN, L., WANG, S., LI, J., TANAKA, K., & OKA, M., 2013, Application of Si improves salt tolerance through ameliorating osmotic and ionic stresses in the seedling of Sorghum bicolor. ActaPhysiologiaePlantarum, 35, 3099-3107.