FIMEK

Journal of Agronomy, Technology and Engineering Management

Article

Sowing Depth - A Significant Factor for Establishing the Optimal Number of Plants Per Unit Area of Soybean

Gordana Dozet [1,*], Vojin Đukić [2], Zlatica Miladinov [3], Gorica Cvijanović [4], Predrag Ranđelović [5], Marijana Jovanović Todorović [6] and Marija Cvijanović [7]

[1] Faculty of Biofarming, Megatrend University, M. Tita 39, Bačka Topola, Serbia; gdozet@biofarming.edu.rs
[2] Institute of Field and Vegetable Crops, M. Gorkog 30, Novi Sad, Serbia; vojin.djukic@ifvcns.ns.ac.rs
[3] Institute of Field and Vegetable Crops, M. Gorkog 30, Novi Sad, Serbia; zlatica.miladinov@ifvcns.ns.ac.rs
[4] Institute for Information Technologies, University of Kragujevac, Jovana Cvijića, 34000 Kragujevac, Serbia; cvijagor@yahoo.com
[5] Institute of Field and Vegetable Crops, M. Gorkog 30, Novi Sad, Serbia; predrag.randjelovic@ifvcns.ns.ac.rs
[6] Institute of Agricultural Economics, Volgina str. 15, Belgrade, Serbia; marijanajovanovic21@gmail.com
[7] University Bjeljina, Pavlovića put bb, Bosnia and Hercegovina ; marijacvijanovic@yahoo.com
* Correspondence: dozetg@gmail.com ; Tel.: +381-65-243-0065 (G.D.)

Received: 21 September 2020; Accepted: 17 November 2020

Abstract: The number of plants per unit area has a great influence on soybean yield. The achieved composition depends primarily on the quality of the seeds, but also on the quality of soil preparation, meteorological conditions, the correctness of the seeder and the depth of sowing. In soybean production, it often happens that the pre-sowing preparation is done immediately before sowing, the sowing layer of the soil does not settle enough, and the sowing is done at a greater depth than optimal. Due to too deep sowing, germination and germination of soybean plants is difficult, the composition is thinned, and the achieved yield is reduced. Too shallow sowing also often occurs due to inadequate tillage or sowing to uneven depths. If the surface layer of the soil dries out after sowing, the seedlings will deteriorate, the composition will thin out and the soybean yield will decrease. The aim of this research is to consider the optimal, shallow, and deep sowing of soybean seeds on the number of plants per unit area, as a condition for achieving maximum soybean yield. By sowing to a depth of 3 to 5 cm in 2017 and 3 to 6 cm in 2017, a set of plants over 400,000 ha^{-1} was achieved, while with increasing or decreasing sowing depth, the number of sprouted plants significantly decreased.

Keywords: soybean; sowing depth; number of plants per unit area

1. Introduction

Sowing is a very important agrotechnical measure that has a direct and indirect impact on the growth and development of soybean plants. Depth of soybean seed sowing affects the time of germination and germination, the achieved set of plants on the plot, which results in the impact on soybean yield. Optimum seeding depth is viewed as a desired goal for all crop establishment systems [1]. The ideal sowing depth depends on the mechanical composition of the soil [3] and the climatic conditions of the region in which the production takes place. The optimal depth of soybean sowing on chernozem soil for the conditions of Serbia is 4-5 cm. On lighter, sandy soils, in conditions of lack of water in the sowing layer, as well as in later sowing, the sowing depth is about 5 cm, and on land where there is enough water and in soils of heavier mechanical composition, with favorable pre-sowing preparation is 4 cm [4]. Sowing depth can greatly influence soybeans ability to emerge and establish a uniform stand [5]. Uniform seed spacing and depth result in better germination and emergence and increase yield by minimizing competition between plants for available light, water, and nutrients [1]. Soybean seeds have high energy and if sown to the optimum depth, there are usually no problems for germination, however, in some years the formation of hard and powerful bark may occur due to heavy rainfall and sudden drying of the topsoil, usually on non-structural soils and on heavier soils without sufficient organic matter. In such conditions, the stem vinegar may break under the cotyledon leaves during germination and the plant assembly may thin out [6]. Seeds buried at different depth may experience varying environmental conditions such as change in oxygen and carbon dioxide concentration, temperature, water and nutrient availability whose changes can affect germination, emergence, growth and development. Too shallow sowing depths results in poor germination due to in adequate soil moisture [7]. In years with a lack of precipitation and water in the soil after sowing, the germination period is prolonged, and a smaller set of plants is established [8]. Sowing with 6.0 cm depth reduced and delayed the emergence due to the greater physical impediment provided by the soil to the seedlings [9]. Therefore, when the soybean seeds are sown deeper, there is more energy expenditure for the hypocotyl to break the layer above the seed [10]. Excessive depths affect the germination, emergence, and development of the plant, mainly due to the decrease in temperature and the availability of O_2 and, consequently, higher accumulation of CO_2 [2, 3]. The plants that emerge first tend to grow more and get more biomass due to photosynthesis in the early stages of growth, except under stressful conditions [13].

The aim of this research was to evaluate the germination of soybean seeds and to achieve a certain composition depending on the depth of sowing.

2. Materials and Methods

In order to assess the impact of sowing depth on the achieved set of plants, a two-year experiment was set up during 2016 and 2017, on land of lighter mechanical composition in the vicinity of Bačka Topola. The experiment was performed in three replications, and the size of the basic plot was 10 m^2 (4 rows of soybeans with a row spacing of 50 cm and a row length of 5 m). Depth of sowing was 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 6 cm, 7 cm, 8 cm, 9 cm and 10 cm, and sowing was done manually on marked plots, opening the furrows to a certain depth. The experiment was performed with a medium - aged soybean variety, the first ripening group, Sava. At the beginning of the sprouting of plants, the plants were counted, and the achieved composition was determined, and during the emergence, the rate of emergence of sinkholes on the surface of the earth was recorded. The results were processed by analyzing the variance of one-factor experiment for each examined year in the program "Statistica 10", and the significance of the differences was tested by LSD test. The results are presented in tables and graphs.

3. Results

The study of the influence of soybean seed depth on the achieved set of plants was performed in two different years, i.e. 2016, which was favorable for soybean production, and 2017, with less favorable meteorological parameters at the time of soybean germination and sprouting. Soybean sowing in 2016 was performed on April 12, and the first sprouts were observed on May 2, i.e. the period from sowing to germination was 19 days, while sowing in 2017 was performed on April 9th, and the first sprouts were recorded on 5th May, i.e. after 26 days. Decade average values for temperatures and precipitation are shown in Table 1.

Table 1. Average temperature (°C) and precipitation (mm) in the period April - May in 2016 and 2017 years.

Year	Month	Decade temperature (°C)			
		I	II	III	**Average**
2016	April	15.9	16.0	10.9	**14.2**
	May	14.3	15.2	20.9	**16.9**
2017	April	12.5	9.9	11.8	**11.4**
	May	14.7	19.1	18.9	**17.6**
Average 1964-2015	**April**	**10.7**	**10.8**	**13.5**	**11.7**
	May	**15.9**	**17.2**	**17.9**	**17.0**
		Decade precipitation (lm^{-2})			
		I	II	III	**Total**
2016	April	9.5	35.0	30.0	**74.5**
	May	27.1	43.1	14.8	**85.0**
2017	April	2.1	41.1	13.8	**57.0**
	May	28.7	5.2	49.0	**82.9**
Average 1964-2015	**April**	**11.6**	**19.1**	**16.2**	**46.9**
	May	**20.0**	**19.2**	**27.8**	**67,1**

The period from sowing to soybean sprouting in 2016 is characterized by higher temperatures in the second decade of April by 5.2 °C, by 2.6 °C lower temperatures in the third decade of April and by 1.6 °C lower temperatures in the first decade of May in relative to the multi-year average. Precipitation was higher in the second decade of April by 15.9 lm^{-2}, in the third decade of April by 13.8 lm^{-2} and in the first decade of May by 7.1 lm^{-2} compared to the multi-year average. In 2017, lower mean temperatures were recorded in the second decade of April by 0.9 °C, in the third decade of April by 1.7 °C and in the first decade of May by 1.2 °C compared to the multi-year average, which affected extension of the period from sowing to soybean sprouting. Precipitation was higher in the second decade of April by 22.0 lm^{-2}, in the third decade of April less by 2.4 lm^{-2} and in the first decade of May by 8.7 lm^{-2} more than the multi-year average. In the first decade of April, 2017, there were 4, and in the third decade 6 windy days, which led to a sudden drying of the surface sowing layer of the soil and difficult germination of soybean seeds sown to a small depth. The recommended number of plants per hectare for medium - growing soybean varieties is 450,000, and the realized number of plants per individual sowing depth is shown in Table 2.

Table 2. Influence of sowing depth on the number of sprouted soybean plants.

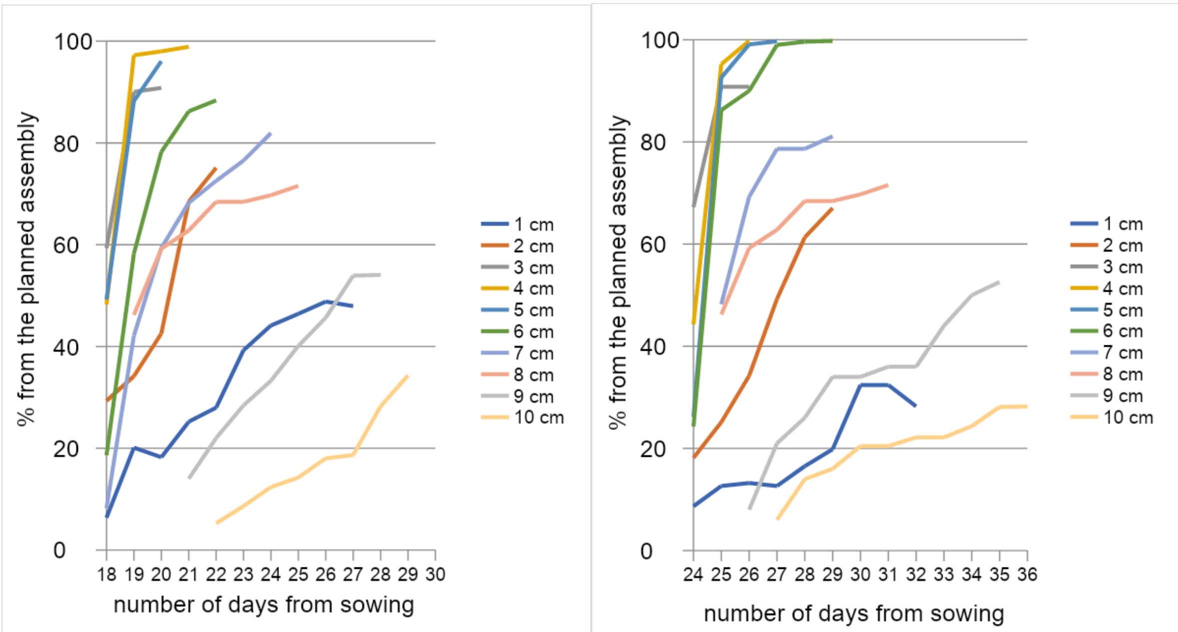
Depth of sowing	Number of sprouted plants	
	2016	**2017**
1	215.67	198.33
2	338.00	301.67
3	427.67	408.67
4	445.00	449.00
5	432.33	448.67
6	397.67	449.00
7	368.67	365.67
8	327.00	322.00
9	243.33	236.67
10	154.33	127.00
LSD 1%	**24.37**	**10.64**
LSD 5%	**17.79**	**7.77**

The highest value for the number of plants per plot in 2016 was achieved at a sowing depth of 4 cm (445.00), 5 cm (432.33) and 3 cm (427.67), which are statistically very significantly higher values compared to sowing depths of 6 cm (397.67), 7 cm (368.67), 2 cm (338.00), 8 cm (327.00), 9 cm (243.33), 1 cm (215.67) and 10 cm (154.33). In 2017, the highest value for the number of nickel plants was recorded at a sowing depth of 4 cm and 6 cm (449.00), as well as 5 cm (448.67), which are statistically very significantly higher values compared to sowing depths of 3 cm (408.67), 7 cm (365.67), 8 cm (322.00), 2 cm (301.67), 9 cm (236.67), 1 cm (198.33) and 10 cm (127.00).

In order to better understand the obtained results, Table 3 shows the number of nickel plants per hectare and the percentage value in relation to the planned set.

Table 3. Influence of sowing depth on the number of sprouted soybean plants per hectare and percentage value in relation to the planned set.

Sowing depth (cm)	number of plants ha^{-1}		% sprouting number of plants ha^{-1}	
	2016	2017	2016	2017
1	215667	198333	47.93	44.07
2	338000	301667	75.11	67.04
3	427667	408667	95.04	90.81
4	445000	449000	98.89	99.78
5	432333	448667	96.07	99.70
6	397667	449000	88.37	99.78
7	368667	365667	81.93	81.26
8	327000	322000	72.67	71.56
9	343333	236667	54.07	52.59
10	154333	127000	34.30	28.22



(**a**) (**b**)

Figure 1. Influence of sowing depth on soybean germination rate and realization of planned set in (a) 2016; (b) 2017.

By sowing at a depth of 3 cm, 4 cm and 5 cm in 2016 and by sowing at a depth of 3 cm, 4 cm, 5 cm and 6 cm in 2017, plant assemblies per unit area of more than 90% were achieved in relation to planned number of plants, and by increasing or decreasing the sowing depth, the number of sprouted plants per unit area decreases.

In 2016, the onset of sprouted was recorded 18 days after sowing, and in 2017 24 days after soybean sowing (Figure 1, 2). The fastest soybean sprouting in both studied years was when sowing soybeans at a depth of 3-5 cm (three days in 2016 at sowing depths of 3 cm and 5 cm and four days when sowing at a depth of 4 cm, i.e. three days in 2017 when sowing soybeans to a depth of 3 cm and 4 cm and four days when sowing to a depth of 5 cm). By increasing or decreasing the sowing depth, the number of days from the appearance of the first shoots to the end of sprouting increased in both years. By sowing at a greater depth, the beginning of sprouting occurred later and the sprouting period was prolonged, while very shallow sowing also prolonged the sprouting period of soybeans. In 2016, the longest germination period was recorded by sowing to a depth of 1 cm (10 days), while in 2017, the longest sprouting period was recorded when sowing at 9 cm and 10 cm (10 days). Sowing to a depth of more than 7 cm in 2016 and greater than 6 cm in 2017 led to the later appearance of sinkholes on the surface of the earth. In 2016, sowing to a depth of 8 cm delayed the start of sprouting of plants for one day, and the sprouting period was seven days, sowing at a depth of 9 cm delayed the beginning of sprouting plants by three days, sowing at a depth of 10 cm by four days, and the sprouting period at sowing at a depth of 9 cm and 10 cm was eight of the day. In 2017, sowing at a depth of 7 cm and 8 cm postponed the start of sprouting for one day, with the period of sprouting lasting five days for sowing to a depth of 7 cm, and seven days for sowing to a depth of 8 cm. The period of sprouting soybeans when sowing to a depth of 9 cm and 10 cm lasted 10 days, with the fact that when sowing to a depth of 9 cm the beginning of sprouting was delayed by two days, and when sowing to a depth of 10 cm the beginning of sprouting was delayed by three days. When setting up the experiment, manual sowing was performed, opening the furrows with a hoe to a certain depth, laying the seeds at the planned distance in a row and burying the furrows, which led to greater aeration of the surface layer of the soil compared to machine sowing. During machine sowing of soybeans, the surface layer of the soil is not disturbed, so the duration of germination would be extended, and the percentage of sprouted plants would be even lower.

4. Discussion

One of the basic conditions for achieving high yields is sowing quality seed [14]. In field conditions germination and germination energy these indicators determine the number of plants per unit area – one of the three basic yield components [15]. In production technology, there are various methods that can improve the germination of soybean seeds [16, 17, 18]. In addition to various methods for obtaining the optimal set of plants, it is necessary to respect all agro-technical measures, and one of them is sowing. It is important to plant accurately in order to achieve good germination, emergence and high plant population [18]. Too shallow sowing results in thin germination due to inadequate soil moisture at the top soil layer [2]. Superficial seeding predisposes seeds to environmental variations, such as water or thermal excess or deficiency, which may culminate in small and less vigorous seedlings [11]. On the other hand, deep sowing (e.g. beyond 6 cm) can significantly affect crop emergence and yield [20, 21, 22]. Seeding depth of 3.8 cm is generally adequate for soybeans but never deeper than 6.4 cm [23]. The ideal soybean sowing depth for best emergence is 2.5 to 3.8 cm under most conditions and never deeper than 5 cm because at deeper levels emergence is delayed, seedling vigour is reduced, and it is harder for a soybean seedling to break through a crust that may have formed [24, 25]. A sowing depth deeper than 5 cm may decrease the emergence, mainly in sandy soils [26]. The final yield of a crop is directly linked to sowing and the adequate formation of stands, and the depth of seed deposition is a factor that is directly related to the success of this process [27]. Significant effect of specific study years was also observed on soybean seed germination. The better results were obtained under more favourable agroecological conditions or in years with rainfall above average [17].

5. Conclusions

Based on these two-year research, the following conclusions can be drawn:

The optimal depth of soybean sowing on sandy soil in the northern part of Serbia is 4-6 cm and at this sowing depth the best set of plants per unit area and the shortest seed germination time is achieved. By increasing the depth of sowing, the beginning of germination occurs later, the sprouting period is extended and a statistically very significantly smaller number of plants per unit area is achieved. Sowing soybean seeds to a shallower depth prolongs the period of plant sprouting and the number of sprouted plants is statistically very significantly lower in relation to the optimal sowing depth.

Funding: This research was funded by MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGICAL DEVELOPMENT OF THE REPUBLIC OF SERBIA, grant number 451-03-68/2020-14/200009, 451-03-68/2020-14/200032 and 451-03-68/2020-14/200378.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author's contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Karayel, D., Özmerzi, A. Evaluation of three Depth Control Components on Seed Placement Accuracy and Emergence for a Precision Planter, *Applied Engineering in Agriculture,* **2008**; 24 (3): 271-276.
2. Aikins, H. M., Afuakwa, J. J., Nkansah, E. O. Effect of different sowing depths on soybean growth and dry matter yield, *Agriculture and Biology Journal of North America*, **2011**; 2 (9): 1273-1278.
3. Zuo, Q., Kuai, J., Zhao, L., Hu, Z., Wu, J., Zhou, G. The effect of sowing depth and soil compaction on the growth and yield of rape seedin rice straw returning field. *Field CropResearch*, **2017**; 203: 47-54.
4. Đukić, V., Dozet, G. Tehnologija gajenja semenskog useva soje: (Svetlana Balešević-Tubić, Jegor Miladinović red.): In *Semenarstvo soje,* 2nd ed; Balešević-Tubić, S., Miladinović, J. Eds; Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija, **2014**; 53-114.
5. Herbek, J. H., Bitzer, M. J. Soybean Production in Kentucky. Part III: *Planting Practices and Double Cropping.* **1988**; Available Online: http://www.ca.uky.edu/agc/pubs/agr/agr130/agr130.htm
6. Đukić, V., Miladinov, Z., Balešević-Tubić, S., Miladinović, J., Đorđević, V., Valan, D., Petrović, K., Kritični momenti u proizvodnji soje, *Zbornik referata 52. Savetovanja agronoma i poljoprivrednika Srbije (SAPS) i 1. Savetovanje agronoma Republike Srbije i Republike Srpske*, Zlatibor, 21-27. Januar **2018**. Izdavač Institut za ratarstvo i povrtarstvo, Novi Sad, 34-44.
7. Sikuku, P. A., Musyimi, D. M., Amusolo, M. Effect of seed depth on germination,growth and chlorophyll contents of Senna spectabilis. *Discovery Science*, **2018**, 14: 84-92
8. Đukić, V. Morfološke i proizvodne osobine soje ispitivane u plodoredu sa pšenicom i kukuruzom. 2009; Doktorska disertacija, Univerzitet u Beogradu, Poljoprivredni fakultet Zemun. 127 str.
9. Modolo, A. J., Trogello, E., Nunes, A. L., Fernandes, H. C., Silveira, J. C. M., Dambros, M. P. Efeito de cargas aplicadas e profundidades de semeadura no desenvolvimento da cultura do feijão em sistema de plantio direto. *Ciência Agrotechnologia*, **2010**; 34 (3): 739-745.
10. Limede, A., Oliveira, C. E., Zoz, A., Zuffo, A. M., Steiner, F., Zoz, T. Effects of seed size and sowing depth in the emergence and morphophysiological development of soybean cultivated in sandy texture soil, *Australasian Journal of Agricultural Engineerin*, **2018**; 12 (1): 93-98.
11. Tillmann, M. A. A., Piana, Z., Cavariani, C., Minami, K. Efeito da profundidade de semeadura na emergência de plântulas de tomate (*Lycopersicon esculentum* Mill.). Ciência Agrotechnologia , **1994**; 51 (2): 260-263.
12. Prado, R. M., Coan, O., Villar, M. L. P. Compressão do solo e profundidade de semeadura na emergência e no crescimento inicial da cultura do milho (*Zea Mays* L.). *Rev Cient Eletrônica Agron*., **2002**; 2: 1-6

13. Zuffo, A. M., Zuffo, Junior, J. M., Carvalho, R. M., Zambiazzi, E. V., Guilherme, S. R., Borges, I. M. M., Ribeiro, F. O., Santos, A. S., Fonseca, W. L., Sousa, T. O. Emergence and early growth of Baruseedlings on different substrates. *African Journal of Agricultural Research* , **2016**; 11 (28): 2481-2485.
14. Milošević, M., Ćirović, M., Mihaljev, I., Dokić, P. Opšte semenarstvo, **1996**; (pp. 53-60). Novi Sad: Institut za ratarstvo i povrtarstvo
15. Crnobarac, J. Uticaj ekoloških faktora na biološka i agronomska svojstva semena i F_1 generaciju nekih genotipova suncokreta. **1992**; Doctoral dissertation. University of Novi Sad, Faculty of Agriculture.
16. Miladinov Z. Predsetveni tretmani semena soje (*Glycine max* L.) u cilju poboljšanja kliavosti i uticaj zemljišne suše na kvalitet formiranog semena. **2020a**; Doktorska disertacija, Poljoprivredni fakultet, Univrezitet u Novom Sadu. str. 133.
17. Miladinov, Z., Balesevic Tubic, S., Crnobarac, J., Miladinovic, J., Canak, P., Djukic, V., Petrovic, K. Effects of foliar application of solutions of ascorbic acid, glycine betaine, salicylic acid on the yield and seed germination of soybean in the agroecological conditions of South Eastern Europe. Zemdirbyste Agriculture, 2020b; 107 (4): 337-344.
18. Djukic, V., Miladinov, Z., Dozet, G., Cvijanovic, M., Tatic, M., Miladinovic, J., Balesević-Tubic, S. Pulsed electromagnetic field - a cultivation practice used to increase soybean seed germination and yield. *Zemdirbyste-Agriculture,* **2017**; 104 (4): 345-352
19. Srivastava, A. K., Goering, C. E., Rohrbach, R. P., Buckmaster, D. R. Engineering Principles of Agricultural Machines, (2nd edn), *American Society of Agricultural and Biological Engineers*, **2006**; Michigan,
20. Aikins, S. H. M., Afuakwa, J. J., Baidoo, D. Effect of Planting Depth on Maize Stand Establishment. *Journal of the Ghana Institution of Engineers*, **2006**; 4 (2): 20-25.
21. Desbiolles, J. Optimising Seeding Depth in the Paddock., **2002**; Available Online: http://www.unisa.edu.au/amrdc/Areas/Proj/SeedTrials/Seeding_depth_article_Kerribee.pdf
22. Mahdi, L., Bell, C. J., Ryan, J. Establishment and yield of wheat (Triticum turgidum L.) after early sowing at various depths in a semi-arid Mediterranean environment, *Field Crops Research*, **1998**; 58: 187-196.
23. OMAFRA Soybeans: Planting and Crop Development., **2009**; Available Online: http://www.omafra.gov.on.ca/english/crops/pub811/2planting.htm
24. Herbek, J. H., Bitzer, M. J. Soybean Production in Kentucky. Part III: *Planting Practices and Double Cropping*, **1988**; Available Online: http://www.ca.uky.edu/agc/pubs/agr/agr130/agr130.htm
25. North Dakota State University Agriculture and University Extension. Soybean Planting Depth is Critical: *Crop Production Information*., **2009**;
    sAvailable Online: http://www.ag.ndsu.edu/procrop/syb/sybpdc05.htm
26. EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de producao de soja-Regiao Central do Brasil-2012/2013., **2011**; Londrina: Embrapa Soja.
27. Pacheco, L. P., Pires, F. R., Monteiro, F. P., Procopio, S. O., Assis, R. L., Petter, F. A. Profundidade de semeadura e crescimento inicial de espécies forrageiras utilizadas para cobertura do solo. *Ciência Agrotechnologia*, **2010**; 34 (5): 1211-1218.