Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v38i4.31837

Harvest growth stages in soybean cultivars intended for silage

Raquel Dias Oliveira[1], Carla Michelle da Silva[1*], Fabio Mielezrski[1], José Sidnei Bezerra Lima[2] and Ricardo Loiola Edvan[1]

*[1]Universidade Federal do Piauí, Rodovia Municipal Bom Jesus Viana, km 01, 64900-000, Bom Jesus, Piaui, Brazil. [2]Universidade Federal da Paraíba, Areia, Paraiba, Brazil. *Author for correspondence. E-mail: carla.mic@hotmail.com*

ABSTRACT. This study aimed to characterize the harvest phenological stages of soybean cultivars intended for silage. Cultivars were evaluated for dry weight of the composite sample, branches, leaves and pods; wet mass of branches, leaves, pods and ground natural matter. This experiment was a 3 x 2 factorial randomized block design, with four replications each, where the first factor corresponds to the harvest stage: R4, R5 and R6; and the second factor refers to two soybean maturity groups (8.0 and 8.1). A significant interaction was detected only for ground natural matter. Higher values of most traits evaluated were observed for the R6 harvest phenological stage. The cultivar with maturity group 8.0 showed higher values for ground natural matter.

Keywords: phenology, forage, *Glycine max* (L.) Merrill.

Estádios fenológicos de colheita em cultivares de soja destinada à ensilagem

RESUMO. Objetivou-se com esse estudo caracterizar os estádios fenológicos de colheita de cultivares de soja destinada à ensilagem. As características avaliadas foram massa seca da amostra composta, das ramificações, das folhas e das vagens; massa úmida das ramificações, folhas, vagens e matéria natural triturada. O delineamento adotado foi o de blocos casualizados em um esquema fatorial 3 x 2, com quatro repetições cada, em que o primeiro fator corresponde ao estádio de colheita: R4, R5 e R6; e o segundo fator diz respeito aos dois cultivares de soja com grupos de maturações diferentes (8.0 e 8.1). A significância da interação foi constatada apenas na matéria natural triturada. Verificaram-se maiores valores para o estádio fenológico de colheita R6 na maioria dos caracteres avaliados. Observou-se que o cultivar com grupo de maturação 8.0 apresentou maiores valores na matéria natural triturada.

Palavras-chave: fenologia, forragem, *Glycine max* (L.) Merrill.

Introduction

Soybean [*Glycine max* (L.) Merrill] belongs to the family Fabaceae. The grain contains about 40% protein, 20% oil, 35% soluble carbohydrates (sucrose, raffinose, stachyose etc.) and insoluble (fiber) carbohydrates and 5% ash, with approximately 14% moisture when *in natura* (Jooyandeh, 2011). Soybean cultivation has great socio-economic interest, due to the high protein content, high grain yield and the possibility of adaptation to different environments (Rocha, Silva, Neves, Sediyama, & Teixeira, 2011).

Given the high protein content, soybean has high potential for animal feed. To this end, the cultivation follows the recommendations for the purpose of producing grain (Dias et al., 2010). The authors also show that for the use of soybean as silage, it is necessary to observe the best harvest stage to get the highest yield and quality, which had already been determined in the 80's by Santos and Vieira (1982). A study conducted by Spanghero et al. (2015) on the effects of stages of soybean plants on mineral composition of silage indicated that the favorable stages for harvesting whole plants are from R4 to R6, because they present high nutritional value for the animal diet.

The use of soybean as silage for animal feed reduces the costs of feedlot production, as it constitutes a viable source of protein, freeing farmers from dependence on unstable prices in the grain market (Gobetti, Neumann, Oliveira, & Oliboni, 2011). In addition, soybean has characteristics that favor the silage production, such as the ability to be grown in various climates, erect, and high content of protein (Rigueira, Pereira, Ribeiro, Garcia, & Cezário, 2015). Stella, Peripolli, Prates, and Barcellos (2016) also claim that the use of soybean silage in ruminant feed is a viable alternative for reducing costs in protein compounds and promote the provision of a balanced diet for a better animal response.

In Brazil and in the state of Piauí, area cultivated with soybean is around 32 million and 637,000 hectares, respectively (CONAB, 2015) and is common the use in animal feed, especially in the Northeast region (Leite, Aguiar, Holanda, & Aureliano, 2014). In case of shortage of forage, farmers can direct soybean crop to produce silage from whole plant (Kawamoto, Touno, Uchino, & Uozumi, 2013), because uneven rainfall has impeded the production of soybean for grains, decreasing productivity. Thus production can be directed to use the whole plant for silage production for animal feed (Gobetti, et al., 2011). For higher production and yield in soybeans, it must be considered the cultivars used, the fertility of the soil and sowing time (Kuss et al., 2008).

Especially because soybean has an intrinsic sensitivity to photoperiod, each genotype of the plant has limitations on the number of hours of light. For this reason, the adaptability of each cultivar changes according to the latitude. The closer to the equator the shorter is the photoperiod throughout the year. The best solution is insertion of cultivars with long juvenile period (EMBRAPA, 2010). In the state of Piauí, distribution takes place as follows: early, up to 110 days, medium, from 111 to 125 days, and late, more than 115 days (Sediyama, Silva, & Borém, 2015). In this way, it is necessary to find cultivars adapted to the region, once these factors define the major development of the plant, in the vegetative stage, and provides the accumulation of dry mass (Craufurd, Vadez, Jagadish, Prasad, & Zaman-Allah, 2013). Given the above, this study aimed to characterize the harvest phenological stages of soybean cultivars intended for ensiling.

Material and methods

The experiment was conducted from December 2014 to April 2015 in the experimental area of the Federal University of Piauí (UFPI Professora Cinobelina Elvas (CPCE), in the municipality of Bom Jesus, state of Piauí, at geographical coordinates 09°04'28" S, 44°21'31" W and 277 m altitude. According to the Köppen and Geiger (1928) classification, the region has Tropical Savana climate (Aw), with two well-defined seasons, the dry season, from May to October; and the rainy season, from November to April. The rainfall varies from 800 to 1200 mm per year; the average temperature is between 26 and 27°C and the average relative humidity between 55 and 65% (Brito, Raabe, Sousa, Melo, & Pedrosa, 2012).

During the experimental period, we collected daily data on average temperature (°C), average relative humidity (%) and rainfall (mm), as illustrated in Figure 1.

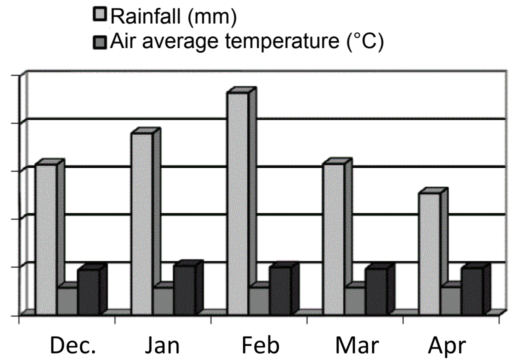

Figure 1. Temporal variation of the average temperature (°C), average relative humidity (%) and total rainfall (mm), during the experiment, 2014/2015 growing season.

This experiment was a 3 x 2 factorial randomized block design, consisting of three harvest stages (R4, R5 and R6) and two soybean cultivars, named cultivar 1 (C1) and cultivar 2 (C2), with four replications. Both cultivars have an indeterminate growth habit; C1 shows maturity group 8.0, wide adaptation to planting and good composition of the ramifications; C2 has maturity group 8.1, high yield potential and optimal plant structure, allowing a better phytosanitary management.

Sowing was made on January 10th, 2015. Each plot consisted of 4 rows, 3 m long, spaced 0.5 m apart; the two side rows and 0.5 m from the ends of the rows were the borders. To obtain a population of 16 plants per linear meter for each cultivar, the determination of the number of seeds sown was made according to the correction of the germination percentage of the batch. At the time of sowing, the seeds were inoculated and treated with 5 x 10^9 colony forming units (CFU) mL ha^{-1} + 140 mL ha^{-1} Fipronil (25 g L^{-1}), methyl thiophanate (225 g L^{-1}) and pyraclostrobin (250 g L^{-1}). Basal fertilization consisted of 125 g superphosphate and 125 g potassium chloride per linear meter, calculated according to the soil analysis (Table 1).

Table 1. Results of soil analysis of the experimental area before the implementation of the experiment.

pH	H+Al	Al	Ca	Mg	K	CEC	SB	P	V
H_2O			$cmol_c\ dm^{-3}$				$mg\ dm^{-3}$		%
5.78	3.3	0.1	2.8	1.2	84	7.52	4.22	29.6	56.9

Cation Exchange Capacity (CEC), Base saturation index (V), total exchangeable bases (SB).

Harvests were performed from March 26th, 2015, respecting the growth stages R4, R5 and R6, when 95% of the plants were at their respective harvest stages. Five plants were taken at random from each plot for analyses of dry matter and number of leaves, pods and branches. Remaining plants in the plots were ground in a stationary shredder to 2 cm average particle size and then ensiled in a 100 mm-PVC pipe 30 cm in length, to a density of 600 kg m^{-3}. Then, the silo was sealed with a polyethylene bag and adhesive tape to prevent gas exchange with the atmosphere.

After each harvest, 5 plants of each plot were separated into branches, leaves and pods for weighing and determining the wet mass of each component (WMB; WML; WMP); then the plants of the plot were ground to obtain the ground natural matter (GNM). After this, the material was dried in a forced air circulation oven at 60°C to determine the dry weight of branches, leaves and pods and the dry weight of the composite sample (DWB; DWL; DWP; DWCS) according to the methodologies used by Neumann et al. (2011); Calvo, Simoneti, and Brancalião (2010) and Cavalieri, Velini, Silva, São José, and Andrade (2012).

The data were transformed using the formula √5 and tested by analysis of variance using Assistat 7.7 beta and means were compared by Tukey's test ($p < 0.05$).

Results and discussion

The results of analysis of variance evidenced a significant effect ($p < 0.01$) for the factor cultivar (C) on traits of ground natural matter (GNM). For the factor harvest stage (S), there was significant effect ($p < 0.01$) on wet mass of branches (WMB), dry weight of the composite sample (DWCS), dry weight of branches (DWB) and dry weight of pods (DWP) and on the wet mass of pods (WMP). It was also observed interaction C x E ($p < 0.05$) for GNM (Table 2).

The wet and dry weight of leaves (DWL and WML) showed no significant values, which may be related be because cultivars have close maturity groups 8.0 and 8.1, and differ little in the number of days/cycle. In addition, cultivars exhibit good adaptation and optimal structure, which may have contributed to non-significance of this trait. Between the harvest stages, there were no significant differences, probably for the translocation of solutes to the reproductive organs, as the assimilates are translocated from the production area, called sources (organs capable of producing photosynthesis) to areas of metabolism or storage of the plant, called sinks (non-photosynthetic organs which do not produce photosynthates) (Taiz & Zeiger, 2013).

For the growth stages of the plants, it was observed that the R6 stage showed the highest percentage of mass in all parameters analyzed (Table 3). Confirming that reported by Rezende, Gris, Passos, Evangelista, and Botrel (2011), who found that yields of soybean mass increased as the cuts were made at more advanced stages.

The breakdown of the factor harvest growth stage was performed and indicated that the R6 stage (Table 4) stood out for most variables, probably because plants, at this stage, have completely filled pods and fully developed seeds (Sediyama, Silva, & Borém, 2015).

The dry weight of the composite sample showed higher means in R4 and R6, which is because R4 plants possessed well-developed leaves and pods, and R6 plants exhibited full and heavy seeds. Unlike R5 plants that showed lower weight possibly because they are at the grain filling period and, at this stage, the photoassimilates are translocated from leaves through the phloem to seed formation (Taiz & Zeiger, 2013), therefore the plant enters senescence and decreases the mass of some structures. In soybean, Rezende et al. (2011) studied the best harvest stage to achieve higher protein yield and found that R4 and R5 stages showed better results, but the cutting at the R4 stage enabled a greater advantage because of the better use of the area when compared to other crops, due to the shorter permanence of soybean in the field. This can also be applied in this work, since R4 showed good performance in the DWCS values.

Table 2. Summary of the analysis of variance for the variables wet mass of branches (WMB), dry weight of leaves (DWL), wet mass of pods (WMP), ground natural matter (GNM), dry weight of the composite sample (DWCS), dry weight of branches (DWB), wet mass of leaves (WML), dry weight of pods (DWP).

SV	DF	QM (g kg^{-1})							
		GNM	WMB	WML	WMP	DWCS	DWB	DWL	DWP
Stage	2	0.1226^{ns}	3.07**	0.05^{ns}	2.66*	0.158**	0.76**	0.008^{ns}	1.04**
Cultivar	1	0.7366**	0.62^{ns}	1.43^{ns}	0.78^{ns}	0.017^{ns}	0.06^{ns}	0.202^{ns}	0.4^{ns}
C X S	2	0.0001*	0.19^{ns}	0.22^{ns}	0.14^{ns}	0.017^{ns}	0.06^{ns}	0.116^{ns}	0.4^{ns}
Error	15	0.0054	0.21	0.54	0.42	0.007	0.04	0.088	0.51
CV (%)		10.4	29.2	24.8	26.7	2.1	15.7	16.2	15.3

**significant at 1%; *significant at 5%; ^{ns} non-significant. Interaction cultivar and stage (C x S), coefficient of variation (CV), mean square (QM), degree of freedom (DF), source of variation (SV).

Table 3. Percentages of wet mass of branches (WMB), wet mass of pods (WMP), wet mass of leaves (WML), dry weight of the composite sample (DWCS), dry weight of branches (DWB), dry weight of pods (DWP), dry weight of leaves (DWL) of the evaluated plants.

Treatments	WMB (%)	WMP (%)	WML (%)	DWCS (%)	DWB (%)	DWP (%)	DWL (%)
R4 Stage	0.18	0.27	0.44	0.58	0.14	0.16	0.27
R5 Stage	0.18	0.37	0.45	0.60	0.18	0.23	0.27
R6 Stage	0.37	0.50	0.48	0.69	0.26	0.26	0.29

Table 4. Mean values for the variables dry weight of the composite sample (DWCS), dry weight of branches (DWB), dry weight of pods (DWP), wet mass of branches (WMB), wet mass of pods (WMP) in the three harvest growth stages R4, R5 and R6 of C1 and C2 cultivars.

Treatments	DWCS ($g\ kg^{-1}$)	DWB ($g\ kg^{-1}$)	WMB ($g\ kg^{-1}$)	DWP ($g\ kg^{-1}$)	WMP ($g\ kg^{-1}$)
R4 Stage	4.095 a	1.01 b	1.244 b	1.10 b	1.87 b
R5 Stage	3.919 b	1.17 b	1.168 b	1.53 a	2.40 ab
R6 Stage	4.198 a	1.61 a	2.278 a	1.82 a	3.02 a
C.V. (%)	2.1	15.7	29.2	15.3	26.7

Mean values followed by different lowercases in the same column are significantly different by Tukey's test at 5%.

The dry and wet mass of branches reached higher values in R6, which can be attributed to the growth habit of the cultivars, as the plant architecture continues to evolve during the reproductive phase (Souza et al., 2014), a fact that has promoted differences between growth stages, resulting in growth and branching of soybean plant. It is extremely important to know the best time to harvest soybean for the production of silage, since advancement of reproductive stage implies changes in the composition of silage of soybean plants (Dias et al., 2010).

The dry weight of the pods showed higher results in R5 and R6, this may be attributed to the grain, the grain filling process, which shapes the size and length of the pods according to the need of the seed shape, reaching larger and heavier pods than at the R4 stage. A similar result was found in the wet mass of pods, the highest mean values were also observed in R5 and R6. This result is seen in Table 3, which shows a higher percentage of DWP and WMP in the last two stages. This is because, at the R4 stage, the pods are fully developed with 20 mm length but without containing seeds, and at R5 and R6, pods increase the weight for containing seeds that are generated within the cavities (Sediyama et al., 2015), thus promoting a greater mass at those stages. Spanghero et al. (2015) considered that the harvest of soybean at advanced maturity stage (R4 to R6), which has high content of protein and neutral detergent fiber, provide quality to ensiled forage. Thus, soybean silage increases the nutritional value and reduces the production of waste (Ribeiro et al., 2009).

As for the ground natural matter, the breakdown of the interaction between harvest stage x cultivars pointed a higher value for C1 at the second harvest stage (Table 5), which is associated with the different cycles of cultivars that promote different behavior of plants (Majee, Shaver, Coors, Sapienza, & Lauer, 2008). There was no significant difference, depending on the harvest stage between the evaluated cultivars.

Table 5. Mean values of the interaction C x E for ground natural matter (GNM) at the harvest stages (R4, R5 and R6) of C1 and C2 cultivars.

Treatments	GNM ($kg\ plant^{-1}$)	
	C1	C2
1st stage (R4)	0.8074 aA*	0.6949 aB
2nd stage (R5)	0.7440 aA	0.6277 aB
3rd stage (R6)	0.7329 aA	0.6294 aA

*Mean values followed by different lowercases, in the same column, or different uppercases, in the same row, are significantly different by Tukey's test at 5%.

In relation to the breakdown of the factor cultivar, there was a significant difference only in the wet mass of the ground matter, which presented the highest mean value for C1 cultivar (0.701 $kg\ plant^{-1}$). This can be because C1 cultivar had larger development than C2 (0.606 $kg\ plant^{-1}$), due to the better adaptation to soil and climatic conditions of the region, where it can be observed the occurrence of short dry periods (Petter et al., 2012), as shown in Figure 1. The months of March and April showed lower rainfall associated with increasing temperature, which may have contributed to the smaller growth of plants and pod formation. Another reason would be related to the maturity group, as C1 with shorter cycle, had been exposed for a shorter period to conditions of water stress. In this sense, C2 may have suffered major negative influence of climatic elements, interfering with growth and development (Setiyono et al., 2011) and, consequently, with the weight of the wet mass.

Conclusion

The R6 growth stage of soybean plants showed better performance for variables analyzed. Cultivar 1 with maturity group 8.0 exhibited superior results in natural matter and in ground wet mass.

References

Brito, D. R. S., Raabe, J., Sousa, W. C., Melo, R. R., & Pedrosa, T. D. (2012). Diagnóstico da arborização das praças pública no município de Bom Jesus, Piauí. *Scientia Plena, 8*(4), 1-6.

Calvo, C. L., Simoneti, J. J. S., & Brancalião, S. R. (2010). Produtividade de fitomassa e relação C/N de monocultivos e consórcios de guandu-anão, milheto e sorgo em três épocas de corte. *Bragantia, 69*(1), 77-86.

Cavalieri, S. D., Velini, E. D., Silva, F. M. L., São José, A. R., & Andrade, G. J. M. (2012). Acúmulo de nutrientes e matéria seca na parte aérea de dois cultivares de soja RR sob efeito de formulações de glyphosate. *Planta Daninha, 30*(2), 349-358.

Companhia Naciona de Abastecimento [CONAB]. (2015). *Acompanhamento de safra brasileira*: grãos (Vol. 2, n. 10). Brasília, DF: Conab.

Craufurd, P. Q., Vadez, V., Jagadish, S. K., Prasad, P. V., & Zaman-Allah, M. (2013). Crop science experiments designed to inform crop modeling. *Agricultural and Forest Meteorology, 170*, 8-18.

Dias, F. J., Jobim, C. C., Soriani Filho, J. L., Junior, V. H. B., Poppi, E. C., & Santello, G. A. (2010). Composição química e perdas totais de matéria seca na silagem de planta de soja. *Acta Scientiarum. Animal Sciences, 32*(1), 19-26.

Empressa Brasileira de Pesquisa Agropecuária [EMBRAPA]. (2010). *Cultivares de soja: Regiões Sul e Central do Brasil 2010/2011*. Londrina, PR: Embrapa Soja.

Gobetti, S. T. C., Neumann, M., Oliveira, M. R., & Oliboni, R. (2011). Produção e utilização da silagem de planta inteira de soja (*Glycine max*) para ruminantes. *Ambiência,* 7(3), 603-616.

Jooyandeh, H. (2011). Soy products as healthy and functional foods. *Middle-East Journal of Scientific Research,* 7(1), 71-80.

Kawamoto, H., Touno, E., Uchino, H., & Uozumi, S. (2013). Comparison of fermentation quality and ruminal degradability between two different harvest timings of forage soybean (*Glycine max* (L.) Merr.) ensiled with the corn-silage system. *Grassland Science, 59*(2), 120-123.

Köppen, W., & Geiger, R. (1928). *Klimate der Erde*. Gotha: Verlag Justus Perthes. Wall-map 150cmx200cm.

Kuss, R. C. R., König, O., Dutra, L. M. C., Bellé, R. A., Roggia, S., & Sturmer, G. R. (2008). Populações de plantas e estratégias de manejo de irrigação na cultura da soja. *Ciencia Rural, 38*(4), 1133-1137.

Leite, D. F. L., Aguiar, E. M., Holanda, J. S., Rangel, A. H. N., & Aureliano, I. P. L., & Júnior, D. M. L. (2014). Valor nutritivo de dietas com inclusões rescentes do subproduto do caju na dieta de ovinos. *Acta Veterinaria Brasilica, 84*(4), 254-260.

Majee, N. D., Shaver, R. D., Coors, J. G., Sapienza, D., & Lauer, J. G. (2008). Relationships between kernel vitreousness and dry matter degradability for diverse corn germplasm: II. Ruminal and post-ruminal degradabilities. *Animal Feed Science and Technology, 142*(3), 259-274.

Neumann, M., Restle, J., Souza, A., Pellegrini, L. G., Zanette, P., Norberg, J., & Sandini, I. (2011). Desempenho vegetativo e qualitativo do sorgo forrageiro (*Sorghum bicolor* x *Sorghum sudanense*) em manejo de cortes. *Revista Brasileira de Milho e Sorgo, 9*(1), 10-15.

Petter, F. A., Silva, J. A., Pacheco, L. P., Almeida, F. A., Alcântara Neto, F., Zuffo, A. M., & Lima, L. B. (2012). Desempenho agronômico da soja a doses e épocas de aplicação de potássio no cerrado piauiense. *Revista de Ciencias Agrarias, 55*(3), 190-196.

Rezende, P. M., Gris, C. F., Passos, A. M. A., Evangelista, A. R., & Botrel, É. P. (2011). Cultivares e estádios de colheita no rendimento forrageiro da soja. *Revista Agrogeoambiental, 3*(1), 9-16.

Ribeiro, J. L., Nussio, L. G., Mourão, G. B., Queiroz, O. C. M., Santos, M. C., & Schmidt, P. (2009). Efeitos de absorventes de umidade e de aditivos químicos e microbianos sobre o valor nutritivo, o perfil fermentativo e as perdas em silagens de capim-marandu. *Revista Brasileira de Zootecnia, 38*(2), 230-239.

Rigueira, J. P. S., Pereira, O. G., Ribeiro, K. G., Garcia, R., & Cezário, A. S. (2015). Soybean silage in the diet for beef cattle. *Acta Scientiarum. Animal Sciences, 37*(1), 61-65.

Rocha, R. S., Silva, J. A. L., Neves, J. A., Sediyama, T., & Teixeira, R. C. (2011). Desempenho agronômico de variedades e linhagens de soja em condições de baixa latitude em Teresina-PI. *Revista Ciência Agronômica, 43*(1), 154-162.

Santos, O. S., & Vieira, C. (1982). Crescimento e qualidade nutritiva da planta de soja (*Glycine max* (L.) Merrill). *Revista Ceres, 29*(161), 107-115.

Sediyama, T., Silva, F., & Borém, A. (2015). *Soja: do plantio a colheita*. Viçosa, MG: UFV.

Setiyono, T. D., Bastidas, A. M., Cassman, K. G., Weiss, A., Dobermann, A., & Specht, J. E. (2011). Nodal leaf area distribution in soybean plants grown in high yield environments. *Agronomy Journal, 103*(4), 1198-1204.

Souza, V. Q., Nardino, M., Follmann, D. N., Bahry, C. A., Caron, B. O., & Zimmer, P. D. (2014). Caracteres morfofisiológicos e produtividade da soja em razão da desfolha no estádio vegetativo. *Científica, 42*(3), 216-223.

Spanghero, M., Zanfi, C., Signor, M., Davanzo, D., Volpe, V., & Venerus, S. (2015). Effects of plant vegetative stage and field drying time on chemical composition and *in vitro* ruminal degradation of forage soybean silage. *Animal Feed Science and Technology, 200*(1), 102-106.

Stella, L. A., Peripolli, V., Prates, Ê. R., & Barcellos, J. O. J. (2016). Composição química das silagens de milho e sorgo com inclusão de planta inteira de soja. *Boletim de Indústria Animal, 73*(1), 73-79.

Taiz, L., & Zeiger, E. (2013). *Fisiologia vegetal*. Porto Alegre, RS: Artmed.

Received on May, 4, 2016.
Accepted on July, 26, 2016.