Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 11, pp.41534-41537, November, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

PRE-HARVEST DESICCATION AND SEED PRODUCTION IN SOYBEAN CROPS

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ARTICLE INFO

Article History:
Received 14th August, 2016
Received in revised form
22nd September, 2016
Accepted 10th October, 2016
Published online 30th November, 2016

Key words:

Glicine max L.,
Agriculture science,
Experimentation science.

ABSTRACT

The physiological maturation, is characterized as the point where the vigor, germination and dry weight are the highest, indicating the ideal time to carry out the harvest in order to produce seeds of physiologically high quality. However, when harvested at this time, the plant is still in a relatively large amount of green and moist leaves and stems which substantially hinder the use of harvesters, besides having greater mechanical injury due to the high water content. Thus, the use of desiccants has emerged as an alternative to accelerate and homogenize the drying of the plants, allowing an earlier harvest. However, there are precautions to be taken in regard to the effects of the use of desiccants in income, on germination and seed vigor.

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Citation: Vinícius Jardel Szareski, Elias Zanatta, Felipe Koch *et al.*, 2016. "A Geographical Appraisal of Health Care Facilities in Lakshadweep Islands", *International Journal of Current Research*, 8, (11), 41534-41537.

INTRODUCTION

Soybean is a worldwide leading commodity being grown commercially in Brazil for just over 40 years (Castro *et al.*, 2006). Brazil occupies the second place, as concerning the world production, belonging the group of the largest producers along the United States and Argentina (Conab, 2015). In the season 2015/2016 were grown more than 33 million hectares with soybeans, with the largest acreage being observed in the Midwest of Brazil (Conab, 2016). In the season 2014/15, the Brazilian states that had higher acreage were Mato Grosso, Paraná and Rio Grande do Sul, and these cultivated 8.9; 5.2 and 5.2 million hectares. In the same year, the highest yields occurred in the states of Roraima, Rondonia, Para, Mato Grosso, Mato Grosso do Sul, Parana and Santa Catarina, where the average yield was higher than 3.0 t ha^{-1} (Conab, 2015). In recent years there has been a significant increase in soybean cultivated area, deserving highlight the Brazilian regions of western Bahia, southern Tocantins, Pará and Piaui, with strong insertion of this crop.

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It is possible to verify that the grain production of this species has increased in greater proportion than the cultivated area, that, due to breeding, biotechnology, mechanization and use of pesticides. Brazilian agribusiness is more than 25% of the gross domestic product (GDP), with the productive chain of seeds being a contributor, since the seeds are considered as a decisive factor in the implementation of high-performance crops, with exemplary profitability. The productivity of the crop is influenced directly by the initial seed quality, as low quality seeds compromise the achievement of the necessary plant stand (Scheeren *et al.,* 2010). In the production of soybean seeds, it is recommended to perform the harvest near physiological maturity, at which point, the seeds reach maximum dry matter accumulation, germination and vigor (Peske *et al.,* 2012; Terasawa, 2008). The seeds of different plants in a population or within the plant do not reach the physiological maturity at the same time, so the physiological maturity refers to a conceptual unit based on a single seed. The evidence that the seed approaches its physiological state, can be variable between species and in the case of soybeans, the change of green to "straw" color of the pod and seeds, the stabilization of the dry mass of the seed and the content water around 45% show the proximity of the point of maximum seed

quality (Peske *et al.* 2012). In production systems focused on production of high-performance seeds, especially in terms of vigor, the seeds should remain the shortest possible time in the field, with minimal exposure to potentially stressful environmental conditions.Thus, in the production of soybean seeds, harvesting is recommended when these structures reach approximately 16 to 18% moisture. However, the point of harvest and physiological maturity usually do not match because, at maturity the seeds are still very wet and imply in a negative way in the mechanical harvesting operations (Marcos Filho, 2015). From the maximum quality point until the harvest, the seeds are between one and two weeks in the field, exposed to adverse climatic condition such as relative humidity fluctuations and air temperature, insect attack and microorganisms, which are some of the main causes of deterioration and discarding of seed lots (Peske, 2014; Marcos Filho, 2015). The deterioration results from a set of physiological, cytological and molecular changes (Santos *et al.,* 2004). This process is irreversible and sped up by environment unfavorable conditions, which can act directly on the plant matrix, adversely influencing the seed formation process and its storage potential. Or, have a direct effect when the stress directly affects the seed and reduces the vigor.

This deteriorating process can lead to loss of vigor and viability which may be related to the reduction of enzyme activity related to cracking stocks and metabolization, the change in defense metabolizing enzymes that tend to lose their effectiveness in severe levels of stress, loss of selectivity of cell membrane system with the release of electrolytes such as sugars, amino acids and other chemicals. Furthermore, in seeds, deterioration can increase the amount of reducing sugar and reduce the amount of soluble sugars and proteins. Obviously, the longer the period of time that the seeds remain in the field or under unfavorable conditions the greater stress period, and so the greater the deterioration.The delay in the soybean harvest in only a few days, when moisture present between 15 to 20%, is sufficient for the loss of quality (Peske *et al.,* 2012). In this context, seed producers make use of desiccants or defoliants products aiming an earlier withdrawal of the seeds from field (Marcandalli et al, 2011; Daltro *et al.,* 2010). The main reason is the ability to anticipate and plan the harvest, increasing the efficiency of harvesters to work with uniform fields, free of unwanted plants and fewer green plants.

Pre-harvest desiccation has been used for many crops, with soybean standing out (Whigham and Stoller, 1979; Durigan & Carvalho, 1980; Costa *et al.,* 1983; Nakashima *et al.* 2000;Lacerda *et al.* 2001; Lacerda *et al.* 2005; Pelúzio *et al.*2008; Kapes *et al.* 2009; Lamego *et al.* 2013; Inoue *et al.* 2012; Pereira *et al.,* 2015; Albretch *et al.,* 2012; Mercandalli *et al.* 2011; Daltro *et al.* 2010; Toledo *et al.,* 2012; Guimarães *et al.* 2012), maize (Magalhães *et al.* 2002), black bean (Penckowski, 2004; Kappes, 2012), wheat (McNEAL *et al.* 1973). Furthermore, the vision of some producers is that the pre-harvestdesiccation of the crop enables the establishment of a second culture in succession, usually maize or sorghum (Inoue, 2012). According to Silva Neto (2011), the procedure provides the best efficiency of use of croplands, machinery, equipment, financial turnover, use of inputs, soil water, weed control and control of some pests and diseases. For soybean cultivars with indeterminate growth habit, there is little information on the most appropriate time for application of pre-harvest desiccant.This fact is even more important, since plants with indeterminate growth have more uneven maturation than those plants with determinate cycle (Inoue *et al.,* 2012). According to Terra *et al.* (2010) herbicides that are more used for desiccation are classified as "non-selective", which, promote the rapid dehydration of the plant and seeds, allowing the execution of the harvest in a period near to physiological maturity.When using products for desiccation it should be considered the product's mode of action, environmental conditions at the time of application, the stadium which the crop is found, traces of toxic waste in seeds, interference in productivity and physiological quality (Lacerda *et al.,* 2005). For desiccation of plants, some farmers make use of glyphosate which is a systemic product, although not recommended for this purpose. It is a post-emergent herbicide, in the chemical group of the substituted glycine, classified as non-selective of systemic action with broad spectrum of action and is absorbed primarily by theregion of plants that present chlorophyll and it is translocated preferably by the phloem to the meristematic tissues.On the other hand, paraquat, diquat and glufosinate are contact herbicides which are rapidly absorbed by the leaves, and present low mobility in the plant not reaching the root system, in contact with the ground become inactive, and are strongly attached to the colloids of the soil, being degraded, including by photolysis (Castro *et al.,* 2002). In Brazil, few products are suitable for use in pre-harvest desiccation.The products registered in the Ministry of Agriculture, are Diquat, Glufosinate Ammonium and Paraquat (Gallon *et al.,* 2012).Currently, the most used products are Diquat and Paraquat with fast action, low translocation in the plant and reduced persistence in soil (Ekmekci and Terzioglu, 2005; Vargas and Roman, 2006).

Pre-harvest desiccation, yield and seeds physiological quality

The shortest time that the seeds remain in the field after they have reached physiological maturity, contributes to obtaining healthier seeds, preventing damage from adverse weather conditions, such as high rainfall in the pre-harvest, the dew and the presence of pathogens (Veiga *et al.* 2007). Studies have been conducted to evaluate the influence of pre-harvest desiccation in plants, with variable results. Kappes (2009), using the herbicide Diquat in the R7.3 stage of soybean plants obtained 81% seed germination, while the results achieved using Paraquat were over 87%.Nakashima *et al.* (2000) using paraquat desiccant applied in R6.5, did not observe that the product does not cause the reduction of productivity and affects seed physiological quality. However, in a study of Bülow & Cruz-Silva (2012) using desiccants in different application times, it was found that the seed vigour is negatively affected by the use of the products.According to these authors, glyphosate herbicide when applied to 117 days after emergence results in seeds with 81% of vigour while the application to 105 days after emergence drastically reduces the vigour of seeds produced, reaching only 7%. Daltro *et al.* (2010) concluded that the use of different herbicides and combinations thereof, desiccation may influence at the vigour of soybean seeds in different forms when applied in R7stage.According to Guimarães *et al.* (2012) desiccation of soybean plants with herbicide Paraquat in R6, R7.2 and R8.1, does not affect crop yield, however, it showed the best germination and vigour values, when this practice was carried out in the two first mentioned stages.In contrast, Lamego *et al.* (2013) claim that the use of desiccants can reduce productivity and quality of seeds, being observed that the application of Paraquat in R6.0 and R7.1 stages reduces by 35 and 13%

productivity. Marcandalli *et al.* (2011) evaluating the application effect of different desiccants applied in different reproductive stages in the physiological quality of soybean seeds, found that glyphosate negatively influences the physiological seed quality, when evaluated by the primary root length test. The herbicide paraquat when applied at the R6 stage, resulted in obtaining seeds with physiological inferior to those obtained with application in R7 and R8 stages. Costa *et al.* (1983) assessing the viability of soybean harvest anticipation observed that the application of desiccant paraquat causes a reduction in the moisture of the seeds, from 30% to 17% after three to five days.

Lamego *et al.* (2013) studied the effect of the time and influence of paraquat application in pre-harvest soybean, found that the vigor of seeds from desiccation of plants in the R7.1 stage proved to be less vigorous and seeds produced without herbicide application, expressed the best results.These results are similar to those of Kappes (2009), who observed that the seeds of the control treatment had greater vigor. Pelúzio (2008) observed a decrease of vigor with a late harvest desiccation in all stages, the largest vigor observed was when the desiccation was done at R7 stage. However, Daltro *et al.* (2010) studied the effects of different desiccants applied pre-harvest and early harvest on the physiological quality of soybean seeds in the state of Mato Grosso, verified that the use of paraquat desiccants, diquat, paraquat + diquat and paraquat + diuron does not affect the yield and physiological quality of soybean seeds, independent of the application time.Nevertheless, with the use of the herbicide glyphosate, there is phytotoxicity to the root system of soybean seedlings, adversely affecting the quality of seeds. Santos *et al.* (2000) concluded that there is no interference of desiccants on productivity and soybean seed germination.

Pre-harvest desiccation risks in seed production fields

Incorrect use of desiccants in pre-harvest culture is a matter of concern in the production of high quality seeds, since the time of desiccation is highly decisive and influential in seed vigor, requiring experience in determining the correct stage of development culture, for its application. Desiccants applied prior to physiological maturity can cause malformation of seeds, especially the occurrence of green seeds, and reduced productivity, reduction of germination and vigor of these structures (Zorato *et al.,* 2003). Some of the herbicides applied in pre-harvest may reflect on the presence of residues in the seeds, causing loss of quality (Toledo *et al.,* 2012). Soybean cultivars that are available in the Brazilian market have determined, indeterminate or semi-determined cycle (Mendonça *et al.,* 2002). Even in determined cycle plants, not all the seeds reach the maximum quality point in terms of strength, dry weight and germination at the same time.When one part of the seed may be able to harvest, another might be in development.Thus, seeds at early stages of development, when subjected to the influence of desiccation of mother plants can not properly complete the development, reducing its strength and therefore its storage potential. The chemical composition of the seeds can be altered with the early harvest because of the outage of flow reserves for seeds or non-allocation of translocated components.Similarly, the delay and the permanence of seeds in the field, also predisposes changes caused by premature deterioration (Marcos Filho, 2015). The desiccation in inappropriate or early stage causes premature leaf fall and may reduce the synthesis of carbonaceous compounds for seeds, as well as lead to a smaller amount of nitrogen available for translocation and allocation of seeds, damaging the synthesis of new amino acids and proteins. Improper formation of reserve structures of the embryo and reserves, as well as the inappropriate formation of cell membrane system, tends to influence markedly the seed vigor and productivity of the originated plants.

Final considerations

In soybean seed production fields, it should primarily focus on the proper crop establishment in terms of soil tillage and sowing, seeking rapid seedling emergence, growth and maturity of more uniform plants; Considering the difference in maturity between seeds of the same plant and the divergence between results of research papers, desiccation in pre-harvest soybean seed production fields should be considered with great caution, and the procedure should be used only in cases of extreme need.

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