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REVIEW ARTICLE

PHYSIOLOGICAL PARAMETERS APPLIED TO THE SOYBEAN SEED STORAGE TECHNIQUES

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ABSTRACT

Soybean (*Glycine max* (L.) Merrill) is originally from China, as the greatest Fabaceae economic importance in the world. Driven by the expansion of demand, particularly internationally, soybean began to expand more strongly in Brazil in the second half of the 70s. It began to be cultivated in Rio Grande do Sul, as a rotation option with wheat. The soybean producers sought to locate their production in higher regions, which usually occur mild temperatures. Some regions are less harsh than others, but in all these regions, the temperature and the moisture content during harvesting are challenges for the production of high quality seeds. In Brazil midwestern, it is common to find temperatures at harvest time, between 28 and 36°C, which, combined with the high moisture content of the seeds, enable the rapid development of fungi and the rapid reduction of seed quality. Seed germination is affected by environmental factors such as temperature and substrate, which can be manipulated in order to optimize the percentage, the rate and uniformity of germination, resulting in obtaining more vigorous seedlings and reducing production costs

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INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is originally from China, as the greatest Fabaceae economic importance in the world (BLACK, 2000). A survey by the National Supply Company shows the importance of soybean production in Brazil, with estimated harvest to February 2016, of 100,933,000 tons, occupying an area of 33,234 million hectares (Conab, 2016). In 1882 occured the introduction of soybean in Brazil, by Gustavo Dutra. The Agricultural School of Bahia did the first studies about it, and in 1891 studies began in São Paulo, in Campinas Agronomic Institute (IAC). At the time, soybean was grown as forage and crop rotation, and the grain had not use in industry yet (Cisoja, 2015). Driven by the expansion of demand, particularly internationally, soybean began to expand more strongly in Brazil in the second half of the 70s. It began to be cultivated in Rio Grande do Sul, as a rotation option with wheat. After established in this state, it expanded to the north, reaching Santa Catarina, Paraná and São Paulo (Mueller, Bustamante, 2002). In the production chain, it is observed that the seed producers and dealers play an important role because the farmers who produce industrial grains require high quality seed to keep the agronomic advantages and raise incomes. The seed industry remains a significant process of evolution in response to new challenges, while promoting the conservation and management of genetic diversity (Risso, 2010). The soybean producers sought to locate their production in higher regions, which usually occur mild temperatures. Some regions are less harsh than others, but in all these regions, the temperature and the moisture content during harvesting are challenges for the production of high quality seeds. In Brazil midwestern, it is common to find temperatures at harvest time, between 28 and 36°C, which, combined with the high moisture content of the seeds, enable the rapid development of fungi and the rapid reduction of seed quality (Barreto; Demito, 2009). The high temperature of the seed after harvest, is inappropriate

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for storage, even at higher altitudes, requiring aeration with cold night air insufflation or cold air.

Physiological quality of soybean seeds

The seed, to be classified as high-quality, needs to fit into patterns that include the sum of physical, physiological, genetic and health attributes. To promote good performance in the field, providing ideal plant population, it must be considered the factors above as well, so the productivity rates will be higher (France Neto *et al*., 2011; Marcos Filho, 2005). The quality control is of fundamental importance to ensure success in seed production, whether in the field phase or the steps of processing and storage (Krzyzanowski *et al*., 2006). Seed quality is directly reflected in the development of culture, generating high plant vigor, uniformity of population and absence of diseases transmitted by seeds (Silva *et al*., 2010). Among the requirements of seed production, the main thing is the quality, because in itare all the genes that characterize the species and cultivar. To obtain quality seeds, the production must be carried out with strict control over all the factors that can reduce the quality. This control extends until commercialization, in order to ensure the genetic quality, physiological, health and physical purity (Panoff, 2013). According to Marcos Filho (2005), the deterioration of seeds can be defined as a degenerative and continuous process that begins at the stadium after physiological maturity, continuing until the loss of viability and the seed death. Depending on the environmental conditions and handling, there can be, therefore, reducing of the seed quality because of the intensification of the deterioration phenomenon. Tunes *et al*. (2011) highlighted that the quality of seeds can be characterized by germination and vigor, which can be defined as the sum of attributes that give the seed the potential to germinate, emerge and quickly result in normal seedlings under a wide range of environmental conditions. The obtaining of high quality soybean seeds depends on the correct management of the production fields. Some studies show that seed quality in a production field is not uniform, being affected, among other factors, by the content of nutrients and compaction of the soil, which present spatial variability (Mattioni *et al*., 2012). The temperature and high moisture content, alone or associated, at the time of harvest, are the major causes of seed physiological quality loss, as they are responsible for soybean seed biodeterioration. Therefore, it is important to decrease quickly at least one of these factors. The easiest and quickest factor to be modified is the temperature (Lazzari, 1997). The same author states that aeration, with artificially cooled air, may represent a significant advance in seed conservation, bringing real benefits to seed producers by reducing the disposal of lots.

Due to its high protein and oil, soybean seed is very susceptible to deterioration, before harvest and during processing and storage. The high temperature, humidity, stress during seed development and maturity can lead to deterioration. This deterioration includes production of abnormal seeds, reduction in germination, vigor and storage capacity as well as reduced nutritional quality (Wang *et al*., 2012). According to Barreto and Demito (2009), the temperature and moisture content are the two key factors in maintaining seed quality during storage. The artificial cooling can provide suitable conditions for storing seeds, because it allows to inflate cold air through the seed mass and keep the temperature low so as to prevent the infection and growth of fungi, regardless of the geographic region. Many companies that store the seeds in bags may also apply the refrigeration technology. It is sufficient to have one or more silos (wood, metal or masonry) that enables cooling the bulk seed soon to be bagged. The temperature must remain between 13 and 15°C. In addition to the genotype characteristics in providing greater or lesser quality of soybean seeds, weather conditions can affect the quality, because places with good rainfall distribution or crops with irrigation favor the production of high quality seeds (Vujakovic *et al*., 2011). The physiological maturity of seeds occurs when the accumulation of dry matter stops. At this point, the seed is at maximum viability and vigor. Typically, this transition is marked by the conversion of the pod color, from green to yellow, and the soybean seed is with approximately 50% of moisture content, being ready to start the next generation (Peske *et al*., 2012).

In the period between physiological maturity and harvest, the seeds are exposed to weather and they suffer deterioration by moisture, aggravating this process in places with hot and humid weather during the ripening stage. The aggravation of the damage is due to the long exposure period of the seed field, which is related to the variation and uneven ripening within the population of plants, which increase the time of keeping the seeds in the field (França-Neto *et al*., 2011). In general, the quality of the seeds decreases after the physiological maturity, depending on weather conditions, especially the temperature and the relative humidity at which they are exposed to, up to the harvest point (Garcia *et al*., 2004).

Purity and germination of soybean seeds

The purity analysis is a feature that reflects the physical or mechanics composition of a lot of seeds, which can identify different species of seeds and inert materials, generally present in a sample and also, to determine the amount or proportion of these constituents in the lot (Brazil, 2009). For the characterization of a lot, as well as their quality and vigor, purity indication, germination and vigor are not enough, which does not exclude their importance (Goulart, 1997). According to MAPA, seed germination can be understood as the emergence and development of main structures, so that the plant can, under favorable conditions, develop in the field (Brazil, 2009). So it can occur, the seedling needs to present well developed root system and aerial part. At the beginning of soybean development, uniform germination and vigorous growth are essential in order to maintain the maximum genetically productive potential contained in the seeds (Silva, 1998; Baudet; Peske, 2007). Temperature is an important factor in seed germination process, determining its limits and the rate of their occurrence, acting also in dormancy induction and breaking (Bewley, Black, 1994). A large number of species have germinal reaction in favor of switching temperature, due to the similarity of what happens to natural, when daytime temperatures are higher than nighttime temperatures (Carvalho; Nakagawa, 2000; Popinigis, 1985). Seed germination is affected by environmental factors such as temperature and substrate, which can be manipulated in order to optimize the percentage, the rate and uniformity of germination, resulting in obtaining more vigorous seedlings and reducing production costs (Nassif *et al*., 1998).

Soybean seeds vigor

Seed vigor exerts direct effects on initial plant growth, reflecting the competitive ability of the crop with weeds, which have lower growth. Also, when in competition maximized by resources, the seed vigor directly influences the productivity of grain and seeds (Dias *et al*., 2010). Particularly in soybean cultivation, the concept of force, has been widespread by the productive sector. The Association of Official Seed Analysts published a good definition of this concept (Aosa, 2009), by which can be understood that vigor are those properties of the seeds that determine their performance for rapid and uniform emergence and development of normal seedlings, even across different environmental conditions. The force, along with germination, reach the maximum potential when the seeds mature, i.e., when they achieve the physiological maturation. However, the conditions that the seed is exposed are going to determine its quality (Garcia *et al*., 2004). For Krzyzanowski *et al*. (2006), the tetrazolium test allows to know the viability and vigor of the seed, and it can diagnose the main problems that can affect their quality: mechanical damage, damage by moisture and by stink bugs, which are the problems that most affect the physiological quality of the soybean seed. This test stands, for soybean, because of its speed, accuracy and the number of information provided. In addition to assessing the viability and vigor of lots, it provides the diagnosis of the causes of reduced quality.

Public research institutions and universities have been concerned, mainly, with the conduction of researches that aim at the adequacy of procedures for determining the vigor, the identification of its efficiency and the attempt to standardize so that the production companies can use this information for the composition of internal quality control programs (Vieira, 1999). Schuch *et al*. (1999) found that the reduction in seed vigor level increased the average time required for radicle protrusion, and reduced the average number of radicles issued per day. The high speed in the emergence and production of seedlings with larger size can provide the plants from the vigorous seeds a head start in the use of water, light and nutrients. Vanzolini and Carvalho (2002) found that the most vigorous seeds produced soybean seedlings with longer length of primary and full root.

Storage techniques of soybean seeds

The storage is defined as one of the important intermediate areas between field production and consumption of crops. This sector suffers decisive socioeconomic influences on quantitative and qualitative availability of food. According to Athié *et al*. (1998), the quality and quantity in storage losses occur mainly due to insects, rodents, birds and deterioration by fungi. These agents are responsible for loss estimated at approximately 10% of the grain produced in the country that, adding to the other losses that occur in postharvest operations, can reach 30% (Lorini *et al*., 2002). Storage is a fundamental practice, which can help in the physiological seed quality maintenance and is also a method which can preserve the viability of the seeds and maintain vigor to the future seeding (Azevedo *et al*., 2003). For Cardoso *et al* (2012), the process of deterioration is unavoidable, but it may be delayed depending on the storage conditions and seed characteristics. From the moment the seeds are stored, preservation of quality is dependent on the initial physiological and storage conditions, that is why these are objects of study of various authors. The seeds under controlled environmental storage conditions (temperature and relative air humidity) allows preserving them for longer periods of time (Baudet, 2007). Due to the conditions of relative humidity and high temperatures in some regions of Brazil, storage is an important step for soybean production. Therefore, the study of problems with the storage of seeds and grains is permanent (Bragantini, 2005), because storage technologies can reduce deterioration of soybean seeds and artificial cooling can store seeds in conventional storage without controlling temperature. In Brazil, the cooling of the seeds is done before bagging, but the success of this technique depends on maintaining the initial temperature of the seeds bagged at safe levels without new cooling cycle (Demito; Afonso, 2009). During soybean storage phase, the damages that contribute most to the reduction in germination and vigor are caused by moisture content and mechanical damage (Moreano *et al*., 2011). According to the authors, these types of damage evolve significantly during storage, resulting in large losses in quality, since lower temperatures during storage reduce the metabolism of seeds (Demito; Afonso, 2009), stabilizing deterioration caused by damages that are already present on the seed before storage.

Cooling of soybean seeds

In Brazil and in other regions with similar climates favorable to the development of pest insects, fungi and other organisms, the application of cooling techniques, using artifically cooled air, has been efficient and economically viable. The technology to cool stored grains is not new, but little used in the countries of tropical and subtropical climate. Its use in Brazil has been economically and efficiently occurring (Lacerda Filho *et al*., 2008). So, the seed cooling technology has consolidated in recent years, which has become very useful for soybean producers in tropical regions. Cooling grains is an effective and economical technique for maintaining the desired qualities of the product, when its use is intended for food, animal feed or seeds (Lacerda Filho *et al*., 2008). At this stage of cooling technology, it is possible to cool bulk seeds, either in silos (static process) or in the processing line (dynamic process). Cooled seeds can be stored in silos or bags, without the need to acclimatize warehouses, avoiding the technical and financial effort that representes the treatment of large air environments. The dynamic artificial cooling of the seeds adds a new step in the process of seeds sorting. However, the technical feasibility depends on a very important aspect, the thermal stability of the seeds, i.e. the maintenance of low temperatures on seeds stored in bags. The thermal stability of the seed depends, among other factors, on the heat transfer between the air inside the warehouse and bagged seed, being a complex physical phenomenon, since it involves heat transfer mainly by conduction and convection (Demito, 2009). In Brazil, this technique is used in various ways, as the system that allows cooling of the seeds at the time of bagging, after processing or in big bags at reception (temporary storage). However, the success of this technique is based on the possibility of maintaining the initial temperature of the seeds bagged at safe levels. With cooling technique it is possible to safely store grains, even with moisture contents above indicated for the conventional storage (Maier; Navarro, 2002).

The control of artificial temperature of stored seed is possible, either through cold chambers that keep the temperature and humidity under controlled conditions or by artificial cooling of the bulk seed mass. Cardoso *et al*. (2004) in a study about cold storage system, called Frioequável®, with soybean seeds treated or not with fungicide, over eight months of storage, found that, even under the cold system, soybeans seeds stored at the top of the piles reduced their physiological quality during storage. Forti *et al*. (2010), evaluating storage conditions on the quality of soybean seeds, observed that there was less progress damage by "humidity" in soybean seeds stored in cold chamber, while the uncontrolled environment was the one what provided further evolution of that damage. These authors observed through germination and vigor tests that uncontrolled storage environment caused further reduction of the physiological potential in soybean seeds as compared with the dry chamber (50% RH and 20 ° C) and cold chamber (90% RH and 10 ° C).

Demito and Afonso (2009) studied the quality of soybean seeds, to evaluate the thermal stability of soybean seeds artificially cooled and stored in conventional storage silos for 140 days. They concluded that soy seeds maintained thermal stability throughout the storage period, especially in the deepest places of the pile, and that the cooled seeds kept the germinating power within the commercial standard (80%). Smaniotto *et al*. (2014) stored soybean seed for 180 days, with three water levels (12, 13 and 14%) in a laboratory environment (27 ° C) and conditioned environment (20°C). By monitoring physiological conditions, they found that seeds with the highest moisture content (14%) lost quality over time. They also concluded that the air-conditioned environment provided better preservation of seed quality in all moisture levels.

By evaluating two lots of soybean seeds stored for three months, one without cooling and the other with seeds cooled to 18°C before bagging, Virgolino *et al*. (2014) observed reduction in seed quality during storage, and that cooling before storage, either in big-bag or in Kraft paper, had no effect in reducing the physiological quality of soybean seeds.

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