Soybean Seeds Produced in Out Season in West of Paraná State – Brazil

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1. Introdution

The soybean [*Glycine max* (L.) Merrill], a legume cultivated by the Chinese during approximately 5000 years, was introduced in Brazil by the end of the 19^{th} century, with great agricultural repercussions as from the end of the 1940s (Marcos Filho et al., 1982). Since it is a vastly applicable species, it has been cultivated extensively throughout the country and at present is one of the main agricultural activities with great relevance in agribusiness. In fact, huge investments have been made and high technological progress has been developed for the increase of its production.

In fact, soybean culture growth in the 1970s has changed the style of traditional agricultural activities in Brazil with developments in production based on modern policies in agriculture and prime matter processing industries. Soybean culture was the main trigger within the Brazilian concept of agribusiness not merely in production volume and in economical aspects in the production chain, but also within the business vision of the rural entrepreneur, suppliers of fertilizers and agro-industrial products so that the sector's competitive advantages may be maintained and broadened.

Soybean is of great importance in the Brazilian production system especially in grain production and in exports mainly for the Chinese market.

In the 2008-2009 harvest, soybean world production reached 210.6 billion tons in an area of 96.3 million hectares. However, the USA is the greatest world soybean producer with 80.5 million tons and a cultivated area of 30.2 million hectares, featuring a mean productivity of 2,666 kg ha^{-1}. Brazil comes second with a production of 57.1 million tons and a cultivated area of 21.7 million hectares, featuring a mean productivity of 2,629 kg ha^{-1} (Companhia Nacional de Abastecimento, 2010). It is expected that the 2009-2010 harvest will reach 64.7 millions of tons.

Soybean is produced in all Brazilian states. The state of Mato Grosso is currently the prime producer, featuring 17.963 million tons in an area of 5.8 million hectares and a mean productivity rate of 3,082 kg ha^{-1}; the state of Paraná comes next, with a production of 9.510 millions of tons in an area of 4.1 million hectares and mean productivity of 2,337 kg ha^{-1} (Companhia Nacional de Abastecimento, 2010).

Such world and national production rate is due to the fact that the legume is the main source of oil production and vegetal protein for human nutrition. It should further be enhanced that soybean may have a functional food role since it may be consumed as flour, milk, textured protein, juice, vitamin, mayonnaise, cream, chocolate, vitamin supplements, soybean salad, roasted and in the manufacture of cakes, biscuits, bread, among others. It is highly important in animal feed especially for the confection of rations for fish, cats, dogs, swine, cattle and birds. It is also used in the industrial manufacture of insecticides, ink, varnishes, soap, cosmetics and other products. Its most promising use, however, will probably be the sustainable fuel called bio-diesel.

Innovatory technologies to enhance soybean culture yield should be sought owing to agro-technological issues coupled to knowledge of nutrition and water requirements and the use of high productive cultivars which are tolerant or resistant to diseases and adapted to the most diverse soil and climate conditions.

Since seeds have an important role within the production system, their production, featuring high physiological and sanitary quality, is of primary importance. Guidelines and strategies should be established so that great quantities of high quality seeds could be obtained to attend to the regional demands of every region.

In the wake of the above considerations, the adaptation of soybean culture within the low productivity period may be very promising even though management still lacks technical and scientific consolidation.

2. Quality and productivity of soybean seed produced during the normal crop period and in the winter

To meet the existing agroindustrial demand for soybean cultivation, quality seed must be available to the market to meet production.

The national production of soybean seed in the 2006/2007 crop season was 959,517 tons for a planted area of 20,693,500 ha, while the demand for seeds for the 2007/2008 crop season was 1,273,146 tons for a planted area of 21,219,100 ha (ABRASEM, 2010).

The seed is considered the most important agricultural input since it is responsible for bringing the genetic characteristics of cultivar performance to the field; at the same time, it is responsible for establishing the desired plant stand, which is the basis for high productivities (Marcos Filho, 2005).

Years of research and genetic improvement are being dedicated all over the world to developing this essential input, the seed, because it transmits specific and desirable characteristics for obtaining higher production and productivity at the smallest possible cost.

Producing seeds obliges the producer to be technically efficient and plan and sell efficiently in order to run a successful business.

Seed production starts with choosing the ideal location, principally in relation to the climate. In this respect, South Brazil, with its many localities distributed throughout the states of Paraná, Santa Catarina and Rio Grande do Sul, is privileged to have cooler temperatures than other regions of the country during flowering, maturation, harvesting and storage of seeds.

Other states also produce soybean seed since they have areas suitable for production, for example, the states of Mato Grosso, Bahia, Goiás, Minas Gerais and São Paulo; however, seed production in these states is insufficient to meet the demand of the planted area.

The fact that soybean seed production is concentrated in some states, together with the small differences between the most suitable sowing periods for each state, favors the exchange of seeds. This means there is a constant flow of seeds between them. This seed flow is especially seen in those states with smaller seed productions, such as Tocantins, Maranhão and Piauí, which are also soybean producers, but do not have a suitable climate for producing soybean seeds and, thus, the seed sown in these states originates from other states.

The preferred crop cycle for multiplying soybean seed in Paraná state has been between October and March, with a field permanence, from sowing to harvest, of 100 to 120 days, depending on the cultivar used to multiply the seeds. The sowing period is variable and follows the agricultural zoning recommended for high quality seed production for each state.

Seed quality can be defined as the group of characteristics which determines its value for sowing, meaning that the potential performance of seeds can only be consistently identified when the interaction of the genetic, physical, physiological and sanitary attributes is considered (Marcos Filho, 2005).

Genetic quality is related to the genetic purity of the soybean seed because this will guarantee that the inherent characteristics of the material to be multiplied will be maintained and expressed in subsequent crops.

Physical quality refers to the physical condition of the seed, which is harmed by the presence of seeds from other species and by inert substances. Stink bug attack, prolonged droughts, high temperatures during maturation, mechanical damage during harvesting and, also, the association of these factors, can affect the physical quality of the material harvested and, consequently, result in a reduction of germination and vigor.

The physiological quality of a seed is its capacity to perform vital functions, characterized by germination, vigor and longevity (Bewley & Black, 1994).

Sanitary quality refers to the presence of microorganisms in the seed, which can contaminate it in the field or during storage.

Among the four quality attributes of seed, those which most influence the seed production system and the quality standards are the physiological and the sanitary.

The physiological quality of soybean seeds can be influenced in the production stage, by the environmental conditions experienced by plants during maturation, post-maturation and pre-harvest, and also by genetic factors. There are references to both biotic and abiotic factors. High temperatures and water stress are the main ones cited, or both together associated with a certain phenological stage. Also insect attack, mainly stink bugs, and disease attack, as well as post-harvest and in the cleaning, drying, storage and transport stages.

The point of physiological maturity of soybean seed, that is, stage R_7, would theoretically be the most suitable for harvesting the seed since it is the point when the best physiological quality is obtained, with maximum viability and vigor. In this stage, the seed moisture content is very high (above 45%) and, after this stage, seed quality will decline due to deterioration.

It is recognized that the maximum quality of soybean seed is attained at physiological maturity, which coincides with the greatest accumulation of dry matter, vigor and germination (Popinigis, 1985). On the other hand, the deterioration process starts at physiological maturity, which is aggravated when seed moisture is reduced below 25%.

Deterioration can be defined as a process which involves cytological, biochemical and physical changes which, eventually, cause seeds to die. The deterioration process in seeds is the principal reason for the loss in viability, which can influence crop yield through a reduction in germination, resulting in a suboptimum plant population per area and a lower performance of the surviving plants (Roberts, 1974). This process has been characterized as inexorable and irreversible by Delouche (1982), being minimum during the stage of physiological maturity and variable between seed lots of the same species and cultivar. Such a process is determined by genetic factors, stink bug attack, environmental conditions in the post-maturation/ pre-harvest stages, harvest and cleaning procedures, as well as storage and transport conditions.

According to Tekrony et al. (1980), the level of reduction in the germination and vigor of soybean seeds varied with the sowing period and with the temperature, relative humidity and rainfall during the maturation and harvest stages.

Like Tekrony et al. (1980), various authors have mentioned the existence of conditions which made obtaining seeds with an acceptable quality more difficult (Marcos Filho, 2005), including for example: high temperatures and high rainfall at maturation, water deficit and high temperatures at grain filling, sting bug attack etc.

As the seed nears or passes full maturation, which happens in stage R_8, that is, when 95% of pods have the typical coloration of a mature pod (Fehr et al., 1971), its vulnerability increases and the causes of damage to the seed increase.

Due to the difficulty of harvesting soybean seed at the point of physiological maturity, they remain "stored in the field", at the mercy of biotic and abiotic factors. Therefore, if climatic conditions are favorable during this period, deterioration problems will be much reduced.

When rainfall is heavy, and there are fluctuations between high and low atmospheric relative humidities, with environmental temperature variations, in the period between the physiological maturation (pre-harvest) and harvest, there will certainly be significant losses in the seed's physiological and sanitary quality. This situation is often observed in most of the savanna regions, where tropical climate conditions predominate. However, in those savanna areas where altitudes are more than 700 m, the same climate conditions are not observed, and they are considered as suitable for producing seeds with a high physiological and sanitary quality. Favorable abiotic and biotic factors in pre and post-harvest, together with a suitable process of seed formation, will result in very significant results for the physiological and sanitary performance of these seeds.

The physiological quality of soybean seed is more strictly associated with environmental rather than genetic factors (Marcos Filho et al., 1985). However, Paschal II & Ellis (1978) mention the existence of genetic variability for physiological seed quality between soybean genotypes, which can be used in genetic improvement programs.

Some studies demonstrate the existence of genotypes which show differences in seed physiological quality. Such differences can exist due to the presence of hard seeds, which are partially or totally impermeable to water penetration through the tegument and, consequently, are less susceptible to mechanical damage and adverse weather.

The total or partial impermeability of soybean seeds to water penetration is a characteristic which can be used to produce soybean genotypes more tolerant to adverse climatic conditions, which may be present after physiological seed maturation.

Regarding sanitary quality, it is well known that in subtropical and tropical regions, the occurrence of unfavorable climatic conditions during the final maturation stage of soybeans, is common. Excess rainfall at this stage, associated with high temperatures, often cause serious damage to seed production, which besides the physiological deterioration process due to fluctuations in humidity levels, also show high infection levels, principally of fungi. Thus, because of these conditions, the presence of diseases in the soybean seeds, has been observed and associated with a low physiological quality.

According to França Neto & Henning (1992), the deterioration of soybean seeds is a result of the interaction of processes and physical, physiological and sanitary changes. Popinigs (1985) believes that, among the theories on seed deterioration, fungal attack is considered one of the main causes. Christensen (1972) mentions that fungi can cause seed death due to direct disease attack or as a result of mycotoxin production. Machado (1988), describing the relationship between seed vigor and pathology, mentions that pathogens can affect seed vigor; but, on the other hand, low seed vigor resulting from non-infectious factors.

The pathogens *Fusarium semitectum* (pod blight), *Colletotrichum truncatum* (anthracnose), *Peronospora manshurica* (downy mildew), *Rhizoctonia solani* (damping-off), *Phomopsis sojae* (pod and stem blight), attack soybeans and are efficiently transmitted via seeds (Henning, 1984).

Although health is a consequence of external abiotic agents, it is influenced by the seed genotype, which provides it with a greater or lesser tolerance to fungal infection.

The association between seeds and pathogenic microorganisms is established during the vegetative development or in the reproductive stage.

The transmission of diseases by seeds is verified in practically all species which breed sexually and various pathogens adversely affect germination (Marcos Filho, 2005).

High temperatures and humidities during seed maturation and harvest can encourage fungal infections, including *Phomopsis* spp. and *Fusarium* spp., principally *F. semitectum*. According to Yorinori (1986), the occurrence of sucking stink bugs (*Euchistus heros, Nezara viridula* and *Piezodorus güildini*),responsible for both direct damage and delaying harvest, help infection by *Phomopsis* spp., *Fusarium* spp. and *Colletotrichum dematium* var. *truncata*.

The most important fungi associated with seed physiological quality, in post-harvest and storage, are the so-called "storage fungi" (Popinigis, 1985). These include mainly species of the genus *Aspergillus* spp. and *Penicillium* spp. Spores and mycelia of these fungi are normally already present on the seed surface when this is stored, that is, they are brought in from the field.

The fungus, *Colletotrichum dematium* var. *Truncata* (giving rise to anthracnose) can cause seed deterioration, seedling death and systemic infection of adult plants. The author points out that *Fusarium semitectum* was present during all the sowing periods in the two crop seasons evaluated. *Fusarium semitectum* is the commonest fungus found on soybean seeds. Some authors consider it a weak parasite or a saprophyte but it was purposely included among the phytopathogenic fungi since it causes problems in laboratory germination, like *Phomopsis* sp. (Henning, 1987). According to Henning (1987) and França Neto & Henning (1992), also cited by Pereira et al. (2000), *Fusarium* spp. can reduce seed germination and its effects can be in addition to those of *Phomopsis sojae.* Among the various *Fusarium* species mentioned, *F. semitectum* is the commonest in soybean seeds in Brazil and, like *Phomopsis* spp., it can affect germination in the standard laboratory test, *Phomopsis* spp. showed a greater incidence during the first sowing period in results from two crop years (due to high humidity at maturation, agreeing with Tekrony (1984).

According to Henning (1987), mechanical damage, and deterioration caused by humidity and damage from stink bugs, are often responsible for poor seed quality and are sometimes associated with *Phomopsis* sp., which causes pod and stem blight.

However, emergence problems in seed lots with a high percentage of *Phomopsis* sp. have not been observed because the fungus makes the evaluation of the germination test in lots with high infection levels more difficult (França Neto & Henning, 1992). This genus has been considered one of the principal causes of seed deterioration.

Pathogens have been cited in the literature as one of the main causes of deterioration, and among the factors which compromise soybean seed quality. Various authors declare that seed health is one of the significant factors in seed performance, and others associate sanitary quality with the climatic conditions present during the crop's final stages (Marcos Filho, 2005). Pereira et al. (2000) state that the physiological and health quality of seeds is influenced by the cultivar and the sowing period.

As mentioned earlier, the quality and productivity of soybean seeds are defined by the interaction between the genotype and the environment and are strongly influenced by crop management.

High productivities are only possible when the environmental conditions are favorable in all the soybean's phenological stages and cultural practices are compatible with economic production. The main management practices which should be considered are: a) sowing during the recommended period for the region; b) choice of the most adapted cultivars for this region; c) use of suitable spacing and densities for these cultivars; and d) monitoring and control of weeds, pests and diseases and a reduction of possible harvest losses to the lowest level (Martins et al., 1999).

On opting for a certain sowing period, the farmer will be choosing a certain combination between the crop phenology and the distribution of climate factors in the producing region, which can result in a high or low yield (Peixoto et al., 2000).

The sowing period is defined by a group of environmental factors, which react among themselves and interact with the plant, promoting variations in the yield and affecting its agronomical characteristics. The environmental conditions which most affect soybean development are: temperature, rainfall, soil moisture and, principally, photoperiod (Câmara, 1991). Cultivars show a large variability regarding their sensibility to sowing date and changes in the crop region (latitudes). For this reason, regional trials, done at different times in the same region are important for evaluating soybean cultivars (Peixoto et al., 2000).

For Brazilian conditions, the sowing period varies depending on the cultivar, the region and the environmental conditions of the crop year, generally with a recommended band, which varies from October to December. In general, November has shown better productivity results in those states where soybean cultivation is traditional (Nakagawa et al., 1983).

Due to Brazil's considerable territorial area, determining a standard sowing period for the whole country is unviable. This was proved by Barni & Bergamaschi (1981), who found that the best period to sow soybeans depends principally on the soil temperature for germination, the atmospheric temperature during the whole plant cycle, the photoperiod after emergence and soil moisture at sowing, flowering, maturation and harvest. These data vary considerably between regions.

Based on these results, therefore, it is extremely important that the sowing period in soybeans grown for seed production, principally in tropical and subtropical regions, has high temperatures associated with a high atmospheric humidity and abundant rainfall.

The sowing period of soybeans for seed production should be adjusted so that the physiological maturity of the seeds occurs when temperatures are cooler and rainfall is less.

In general, the best productivity in Brazil is obtained when soybeans are sown between the end of October and mid-November. However, to produce high quality seeds, the best sowing periods are between mid-November and mid-December.

Based on this, research has been done in most of the principal soybean producing states in Brazil with the objective of comparing the quality of seed produced in later periods to that sowed conventionally (in October/ November) and, also, the productivity of different cultivars. Studies by Pereira et al. (1979), Motta et al. (2002), Ávila et al. (2003), Dallacort et al. (2008), Braccini et al. (2010) in Paraná state; Paolinelli et al. (1984) in Minas Gerais; Tragnago & Bonetti (1984) in Rio Grande do Sul; Nakagawa et al. (1983, 1984, 1986) in São Paulo; Pereira et al. (2000) in Goiás; Costa et al. (1995) in Mato Grosso, evaluated both the quality and the productivity of soybean seed sown at different times (October to December), using different cultivars with groups having a distinct maturation (early, medium and late-maturing varieties).

Most of the authors cited previously mentioned that the seed quality of early-maturing cultivars, grown during the spring-summer period, is normally inferior to that of late-maturing cultivars, grown during the same period. This is because normally the maturation stage of the early and semi early-maturing cultivars, coincides with the period of greatest rainfall and atmospheric relative humidity, which normally leads to higher microorganism attack, thereby reducing the physiological quality of the seeds, which is supported by Miranda et al. (1986).

The explanation of the above is that when early-maturing soybean cultivars are sown during periods which give maximum productivity (October/ November), maturation and harvesting occur in February and the beginning of March. This period often coincides with fluctuations in rainfall and high temperatures, which adversely affects seed quality.

However, independent of the cycle, there is a declining linear tendency for the productivity of the cultivars used, as the sowing date distances itself from the ideal. Experimental results commonly show quadratic response curves when the recommended period for sowing is between the extremes, that is, when sowing is neither anticipated nor late. However, such responses do not always coincide with obtaining maximum seed quality, although relevant studies concentrate on the main crop period ("crop season") and rarely seek to investigate the second crop situation grown between the main summer crops.

Some forecasts made by seed producers for sowing dates during less rainy periods (autumn-winter), indicate that growing soybeans for seed production in the inter-crop (off season) period can be an alternative for obtaining good quality seed, since the rainfall intensity and atmospheric relative humidity are more suitable. This is the case as long as the cultivars used are adapted to the region and show stability and juvenility.

The inconvenient factor is the risk of unfavorable climatic conditions during seed maturation (which can be solved by supplemental irrigation), high stink bug populations and higher rust incidence (solved by efficient agrotechnological management).

In the higher altitude savanna regions, during the inter-crop period, with irrigation and control of the available water, and with suitable temperatures, high quality seed can be obtained. This is possible in some producing regions but there have been no supporting technical-scientific studies, especially after the appearance of soybean rust and the consequent legal restrictions to crop planting.

Another relevant aspect in producing soybean seeds during the inter-crop period is the reduction in seed storage time, since the time between storage and the next sowing will be 8 months, during which time the seed quality obtained in the field should be preserved.

The preservation of seed quality during storage, that is, from harvest until planting, is a fundamental aspect to be considered in the productive process, since the efforts spent in the production stage may not be effective if seed quality is not maintained at least until the sowing period (Oliveira et al., 1999).

In the edaphoclimatic conditions of Paraná state, specifically in the west of the state, Albrecht et al. (2009) made one of the few published studies, which specifically deals with soybean seed production during the inter-crop period. The authors found that soybeans sown between 15/01 and 15/03 did not produce seeds with a high physiological and sanitary quality. However, for most of the cultivars used, the standard of seed was the same as that stipulated for the genetic seed class and basic seed.

Probably, in the study by Albrecht et al. (2009), the use of seeds from early-maturing cultivars, associated with late planting in the inter-crop period (beginning of March), resulted in low productivity and also low seed quality.

Early or very early-maturing cultivars may not be the best options since because of the photoperiod for the latitude studied, together with a lack of the juvenility characteristic, they may cause an excessive shortening of the cycle.

A very short cycle stops the adequate processing of photoassimilate accumulation in seeds, as well as their adequate formation and development. Also, those crops without any supplemental irrigation and with early-maturing cultivars are more vulnerable to the consequences of stress from water deficits (which also stops the formation of seeds with a high physiological potential).

Therefore, it is probable that the conditions at physiological maturity have been, or will come to be, favorable to planting in the inter-crop period: but, if the water, temperature and photoperiodic needs of the soybean plant are not satisfied to ensure its adequate growth and development, the production of soybean seed with a high physiological performance will be prejudiced.

Another important aspect of producing soybean seeds in the inter-crop period is the certainty of reducing the risk of gene flow between transgenic and conventional cultivars with the same cycle.

Maintaining the genetic attributes of the cultivar whose seeds will be multiplied is fundamentally important in seed production. In this case, attention should be given to the production of transgenic seeds during the same periods as conventional seeds.

An increase in the cultivation of transgenic plants has been observed in the last ten years. The world area of GMO plants is estimated at 80 mm ha, with soybeans resistant to glyphosate herbicide (*Roundup Ready* soybeans - RR), being especially significant, since it is the most widely planted transgenic crop, with approximately 61% of the total world area.

Celeres (2010) estimates that about 75% of the total area sown to soybeans in Brazil in the 2010/11 season will be with transgenic varieties, which generates high demand for seeds.

Included in the norms for producing transgenic soybean seed is a regulation for a minimum isolation distance, which can be either in space or time, between different transgenic cultivars and between transgenic and conventional cultivars, with the aim of avoiding the risk of gene transmission to future generations. This is because of the possible gene flow via pollen (Ray et al., 2003) between one plant and another, to maintain seed purity.

In this context, the possibility of non-transgenic soybeans being pollinated by transgenic cultivars and vice-versa has been raised. A negative answer is immediately obvious since it is known that soybeans are essentially autogamous, with complete flowers, and the masculine and feminine organs protected within a corolla, with fecundation occurring before the flower opens (cleistogamy). However, pollen grains can be dispersed in the environment by entomophily, that is, by insects, principally by bees, among others, which visit the flowers and can transport the pollen and pollinate the flowers of different plants; besides insects, the wind also functions as a pollinating agent and because of this, the rate of cross pollination is generally lower and close to 1% (Borém, 1999). Sediyama et al. (1970) in Viçosa, Minas Gerais state, working with plants in direct contact with each other and with plants very close to one another, observed a natural crossing of 1.3% and 0.03% respectively. In another study in Capinópolis, Minas Gerais state, a value of 0.9% was observed for rows in direct contact. On the other hand, Vernetti et. al. (1972) found the percentage of natural crossing to be 0.03% in Ponta Grossa, Paraná state, and 1.22% in Pelotas, Rio Grande do Sul state.

These studies prove that, under normal field conditions, cross pollination is low (Ahrent & Caviness, 1994) and the variations in the level of cross fecundation are related to the climatic conditions of the crop year, the genotypes, the environment and plant isolation. The values for cross fecundation in soybeans are low and it occurs principally between adjacent plants whose flowering coincides. Nelson & Bernard (1984) observed that an isolation distance of 10 m for soybeans would eliminate almost all pollen contamination. Ahrent & Caviness (1994) demonstrated that the frequency of cross pollination can reach 2.5% in some cultivars and that insect, especially Hymenoptera, can act as pollinators (Erickson et al., 1978).

Results from some studies done over the last three years with non-transgenic soybeans have shown that the occurrence of cross pollination at distances greater than 4.6 m is rare (Ahrent & Caviness, 1994). Boerma & Moradshahi (1975) consider a distance of 7 m safe since cross pollination was 0% at this distance, although obtaining this distance between one seed producing field and another is difficult at present, due to the increase in cultivated soybean area.

The scientific results of genic flow between non-transgenic and transgenic cultivars are very contradictory.

Due to this situation, seed production, principally of the genetic category during the inter-crop period, when large soybean areas are not planted, could be an interesting solution for reducing the risk of gene flow to low levels, considering the sowing period, the presence of insects with pollinating potential, and the velocity and direction of the winds.

The problem is not only field contamination but also the cleaning of the harvesting and cleaning equipment. Winter weed management is another worry, although different crops introduced into the production system through crop rotation, facilitate the use of different herbicides with distinct mechanisms of action, minimizing the selection of resistant weed biotypes.

Strategies which stop soybean crops being planted in succession are indispensable for system sustainability, and improve nutrient cycling, weed control, and the propagation of diseases and pests in the crop.

As long as the no-planting period, regulated by government decrees (with the aim to breaking the “Green bridge” which maintains the asian rust in the environment), is respected, the production of transgenic soybean seeds in certain environments would be extremely valid.

The growing of soybeans, whether it be transgenic or conventional, during the inter-crop period and focusing on seed production, should, besides the respective legislation, respect agronomical criteria which will identify suitable areas and sowing periods. Therefore, edaphoclimatic and phytotechnical studies are needed, considered together with available knowledge (presently scarce), to develop a rational zoning for soybean for the inter-crop period.

3. Ecophysiology and agroclimatic aptitude of soybean production in a second crop

Wherever plants grow, they will be subject to multiple stresses, which will limit their development and chances of surviva.

Soybean is a crop which may suffer a range of physiological and morphological changes during development when its ecophysiological needs are not met.

Water availability for soybeans is important, principally in two development periods: germination and emergence; flowering and seed filling. During the first period, both water excess and deficit adversely affect a good uniform plant population. The soybean seed needs to absorb at least 50% of its weight in water to guarantee good germination. In this stage, the soil water content should not exceed 85% of the total water available or be less than 50%.

The water needs of soybeans increase with plant development, reaching a maximum during flowering-grain fill (7 to 8 mm dia^{-1}), and decreasing after this period.

Studies on agroclimatic zoning are primarily developed with the objective of satisfying water demand through the creation of water balances. The aim of agricultural zoning is to identify suitable areas throughout Brazil and recommend when soybean seeds should be sown with the least climatic risk.

In Paraná state, as in other regions, the water balance is estimated by using the following climatic and agronomical variables:

a. rainfall and temperature: historic series with an average 20 years data are used, with records from 191 rainfall and 29 climatological stations in the state;
b. potential evapotranspiration: estimated for 10-day periods, by applying the Penman-Monteith method for each climatological station in the state;
c. crop cycle and phenological stage: the stages of germination/ emergence, growth/ development, flowering/ grain fill and maturation, were considered for simulation purposes. Cultivars were classified into three groups with homogeneous characteristics: Group I ($n < 115$ days); Group II (115 days $\leq n \leq$ 135 days); and Group III ($n > 135$ days), where *n* is the number of days from emergence to complete maturation;
d. crop coefficient: experimental data available from scientifically recognized publications;
e. maximum availability of soil water: estimated as a function of the effective depth of the roots and soil water capacity.

Soil Types 1, 2 and 3, with a water storage capacity of 30, 50 and 75 mm respectively, are considered. The simulations of water balances are done for 10-day periods.

The mean values of the Satisfaction Index of Water Needs – SIWN (expressed by the relationship between real evapotranspiration and the maximum evapotranspiration - ETr/ETm), for sowing date, phenological stage and geographic location of the pluviometric and climatological stations consulted, are considered. The flowering/ grain filling stage was considered the most critical regarding water deficit.

Municipalities are thought suitable when in 20% of their territory the SIWN is greater or equal to 0.65, in at least 80% of the years evaluated.

Zoning is done primarily to minimize the negative impact of water restrictions on plant growth and development. Significant water deficits during flowering and seed maturation cause physiological changes in the plant, such as closure of the stomata and rolling up of the leaves. Consequently, this causes premature leaf and flower abscission and also pod abortion, resulting in less productivity (Santos, 2008).

To obtain a maximum yield, water needs for the soybean plant during its whole cycle vary between 450 and 800 mm, depending on climatic conditions, crop management and cycle length.

Water availability is one of the most important environmental factors for plant growth and development. Water deficit, caused by drought or soil salinity, is one of the most serious environmental problems limiting agricultural production in various regions of the world.

The response of plants to water stress depends on the stage they are in, as well as its severity and duration. Climatization to environmental stress results from integrated events which occur at all organizational levels, from the anatomic and morphological to the cellular, biochemical and molecular. Leaf wilting in response to water deficit reduces water loss from the leaf and also exposure to incident light, thus reducing heat stress to the leaves.

The temperature directly influences all crop stages, that is, germination, growth, flowering and fruiting, as well as respiration, photosynthesis and water and nutrient absorption.

The optimum temperatures for soybeans lie between 20 and 30ºC, with 30ºC being the ideal temperature for development. The soil temperature range suitable for sowing varies from 20 to 30ºC, with 25ºC the ideal temperature for rapid and uniform seedling emergence.

The vegetative growth of soybeans is small or nil in temperatures less or equal to 10ºC. Temperatures above 40ºC adversely affect the growth rate, causing damage to flowering and reducing pod retention capacity. These problems increase with water deficits.

The minimum temperature for the beginning of the reproductive stage of soybeans varies according to the demands of each cultivar, but under Brazilian conditions it is estimated at 13ºC, since soybean flowering is only induced at temperatures above this. Maturation can also be accelerated by high temperatures (Santos, 2008).

Maturation can be accelerated by high temperatures. When associated with high humidities, high temperatures can reduce seed quality, and when associated with low humidities, they predispose the seeds to mechanical damage at harvesting. Low temperatures associated with rainfall or high humidity at harvest can delay harvesting as well as cause green stem and foliar retention.

Considering the temperature needs of soybean, and the possibility of stress caused by temperature extremes, it is believed that in order to grow soybeans, besides the water regime, temperature availability in the different crop stages must also be understood. Regarding the possibility of growing crops outside the main crop cycle or between the summer crops, where temperature extremes may be a fact, the climatic temperature variable must be considered when planning the soybean crop. Thinking specifically of the winter crop in southern Brazil, low temperatures may occur after flowering in soybeans planted later, which may limit the viability of productive systems planting soybeans during the winter months.

In the case of soybeans, the climatization of different cultivars to certain regions depends on the photoperiodic needs, as well as on those for water and temperature.

Sensibility to photoperiod varies between cultivars, that is, each cultivar has its own critical photoperiod below which flowering is stimulated. The typical photoperiodic effect in soybeans is a reduction in the period between seedling emergence and the beginning of flowering, and consequently, of the crop cycle. However, cultivars which have a long juvenile period show more adaptability so they can be used in wider bands of latitude (places) and sowing periods.

Therefore, the typical photoperiodic effect in soybeans is a reduction of the period between seedling emergence and the beginning of flowering and, consequently, of the crop cycle, when a cultivar is taken to a lower latitude region or when sowing is delayed. This also results in the formation of shorter plants with insertion of the first pod at a lower level, and reduction of foliar area and productivity (Sediyama et al., 1972).

Soybean cultivation at lower latitudes and outside the conventional period in southern Brazil can result in plants which anticipate flowering, reduce vegetative growth and, consequently, the productive potential. Genetic improvement with the production of genotypes having a long juvenile period is a strategy which can be used. Therefore, the planting of soybean cultivars with longer cycles as a second crop in Paraná and other southern Brazilian states, preferentially with a juvenile characteristic, is recommended. Based on these assumptions, some farmers have been sowing cultivars normally planted in the Brazilian Savannas (Cerrado region) as a second crop in Paraná, since many of these savanna cultivars (low latitude conditions) have a long juvenile period.

Ecophysiologically, soybeans are demanding for various factors, such as photoperiod, temperature and water. In this context, under natural agricultural conditions, plants are often exposed to environmental stress. The environmental stresses are external factors, which commonly produce adverse effects resulting in low soybean productivities as well as reducing seed quality and oil and protein conten.

Considering that the soybean plant is influenced by various factors throughout its cycle, it is relevant to emphasize that crop management can influence plant development and yield, and also seed quality and chemical composition. Examples of management include the sowing period, cultivar selection, choice of plant population, fertilizer levels and pesticide regimes.

Atypical climatic situations in Brazilian agriculture are influenced by phenomena such as La Niña and El Niño, among others.

Based on global warming studies, it is believed that there will be significant changes in agriculture in the world, including Brazil. Research studies in Brazil have forecasted a new geography of agricultural production, indicating an increase in areas unsuitable for growing soybeans (EMBRAPA SOJA, 2008), that is, areas which used to be suitable for the crop, sown in November, December and January (according to the study by EMBRAPA SOJA, 2008), will become unsuitable.

According to EMBRAPA SOJA (2008), soybeans are the crop which should most suffer from global warming if sowing conditions stay as they are and no genetic modifications are made (this should not be the case since new varieties are already being studied). By 2017, the area of low risk in Brazil can be reduced to 60% of the present area, due to the increase in water deficits and the possibility of more intense summer droughts. The southern region and the Northeastern savannas will be the most affected areas.

Changes in global and regional climates have a significant influence on human and economic activities. Studies of the climate variations in the Southern Region of Brazil have analyzed rainfall anomalies (Casarin & Kousky, 1986).

Temperature, rainfall and atmospheric relative humidity are meteorological characteristics which directly influence environmental conditions. The world variation in atmospheric temperature is one of the most important climatic parameters strongly influencing various areas, such as agriculture, fishing, cattle raising, engineering, temperature and urban comfort, and energy production, among others.

Many aspects of agricultural production can be adversely affected by the weather. Fox et al. (1999) believed agricultural forecasting to be very important, principally for rainfall, resulting in the development of forecasting methods. Many researchers have reasoned similarly, developing methods for evaluating when and how much it rains and the yearly rainfall distribution.

Foreknowledge of these elements, the plant's reactions to their availability, and the critical limits in agricultural management practices, are essential for the plant's ecophysiological success (Leal, 2001).

Considering that soybeans are influenced by various factors during their cycle, the choice of when to sow must be considered as the cultural factor, which by itself most influences plant development, crop production and also seed quality.

The sowing period is a factor which affects not only production but also seed performance because it exposes the seeds to climatic factors and is, therefore, a fundamental parameter for obtaining better quality seeds (Costa et al., 1995).

The sowing period can be adjusted to avoid losses from low rainfall during the critical periods of soybean development for moisture, that is, at its establishment, flowering and seed formation (Barni & Bergamaschi, 1981).

Innumerable research studies, which show the importance of defining the sowing period, have been done in various soybean producing areas of Brazil, with the objective of establishing the most suitable sowing period (Motta et al., 2002).

Some studies have indicated that the sowing period should be established so that the seed maturation stage occurs when temperatures and rainfall are less (França Neto & Henning, 1984).

In the climatic conditions of north Paraná state, early maturing soybean varieties, sown at the beginning of October, should mature in the second half of February, which coincides with periods of high temperatures and excess rainfall. This results in seeds with a lower physiological quality and a high degree of deterioration from humidity (Pereira et al., 1979).

Another study by Val et al. (1985) in this same region, which planted nine soybean cultivars at five different sowing periods, demonstrated that, in general, the best sowing period was in mid-November, when most of the cultivars reached their best productivities and plant heights. Anticipating the sowing for September adversely affected the performance of most cultivars, reducing not only the productivity but also plant height and pod insertion.

The influence of the environment on seed development is seen principally in variations of size, weight, physiological quality and health (Marcos Filho, 2005). Experimental studies supply important information, which can be used to differentiate cultivars and indicate the best times for sowing in a certain region for a certain cultivar (Motta et al., 2002).

The preferential period for sowing soybeans in Paraná state is November. In general, for the main producing regions of Brazil, higher productivities are obtained when soybeans are sown between October 15th and December 15th. For most regions, soybeans sown at the end of December and in January can result in yield reductions of between 10 and 40% compared to those sown in November (EMBRAPA SOJA, 2008).

The best results for yield and plant height, in most years and for most cultivars, are obtained for soybeans sown between the end of October and the end of November. In general, soybeans sown in the second half of October produce shorter plants with higher yields compared to those sown in the first half of December. However, in some areas, it is possible to obtain plants of a suitable height with a good yield when seeds are sown in the first half of October (EMBRAPA SOJA, 2008).

For situations where the aim is to plant autum-winter corn after the soybean crop, the planting of early-maturing soybean varieties is recommended, preferably sowing between the end of October and November 15th. However, the use of early-maturing cultivars can result in shorter plants with an inadequate canopy closure leading to greater weed effects in the crop. This problem can be accentuated if there is a lack of rainfall during the period at the end of November, beginning of December, which has been common in Paraná state (EMBRAPA SOJA 2008).

According to EMBRAPA SOJA (2005), anticipating sowing would be by planting before October 15th. Crops sown before this date tend to show a longer period between sowing and seedling emergence (due to the low nocturnal temperatures) and also shorter plants, resulting in harvest losses. This can be done in hotter regions of the state, where the winter is humid, soils are extremely fertile and temperatures favor seedling emergence from the beginning of October. These conditions are commoner in the western region of Paraná state, located between the Piquiri and Iguaçu, which are at a lower altitude and closer to the Paraná River.

The second soybean crop in the western region of Paraná state, as well as in other producing regions of Brazil (mainly the savanna region), is a common practice among farmers and can be an option for producing soybean seeds during the offseason or intercrop period (soybeans cultivated during a non-conventional period). Also, if there is no production of commercially acceptable seed, there still remains the possibility of reaching acceptable standards for producing basic seed (75% germination).

However, soybean production under conditions occurring between the summer crops or in the winter suffers from ecophysiological restrictions. Both biotic and abiotic factors can limit the possibility of winter soybeans becoming a second soybean crop and generating significant income, as is the case with corn.

Some productive systems in which soybeans would be sown after soybeans or after dry beans, cotton or sunflower, would be unviable in phytosanitary terms, especially regarding disease incidence in the large crops, such as Sclerotinia stem rot (*Sclerotinia Sclerotiorum*) and nematodes.

Asian rust, (*Phakopsora sp.*), is also seen as a real problem, especially when soybeans permit the so-called "green bridge" for the rust inoculum. Diseases such as powdery mildew (*Microsphaera diffusa*) in soybeans can also increase significantly under some climatic conditions in the winter crop, where the climate is warmer and dry. Insects, such as stink-bugs (*Nezara viridula, Euschistus heros, Piezodorus guildinii* and *Dichelops furcatus*), can be severe problems since they will find an available food source to keep their populations at potentially damaging levels.

In the case of weeds, due to the need for immediately sowing after the summer crop, careful management would be necessary to minimize interspecific competition between weeds and the crop, as well as the perennization of weed species in the field and even the selection of resistant biotypes through the continuous use of herbicides with the same mechanism of action. The solution in this case would be rotation in the area between transgenic and non-transgenic cultivars.

With regard to the abiotic factors, serious restrictions could occur due to low temperatures and water deficits during a second soybean crop cultivated in Southern Brazil. On the other hand, a second soybean crop in the savanna region would only need a water supplement supplied via irrigation because of the sowing season.

The barriers to the development of soybean agroecosystems in the winter months can be solved with strategies which range from the use of suitable sowing periods to the implementation of an efficient and prompt agrotechnological management.

Together with ecophysiological perceptions and the need for suitable technologies for soybean cultivation during the winter months, the advance of research (public and private) in the tropical and subtropical conditions of Brazil is indispensable for soybeans to be a viable option during the intercrop period. This cultivation is important since it is a valid tool for obtaining quality seeds.

4. Perspectives and final considerations

Even after the significant conquests by Brazilian agribusiness with technological advances, which have allowed the expansion and viability of crops, as in the case of soybeans, more progress is still possible due to the existing large potential, whether it is the environment still to be explored or the human capital involved.

One of the greatest examples of the phytotechnical revolution in soybeans is its adaptation to cultivation at low latitudes, through a laborious process of genetic improvement. The rational management of poorer land, which has been making soybean cultivation possible in regions with sandy and low fertility soils, such as in the savanna areas and in the Caiuá sandstone region (northwest Paraná), has also been mentioned. The introduction of transgenic soybean genotypes, especially in the last decade, has motivated a new revolution after the "Green Revolution" (using agrochemical and industrialized inputs), a so-called "Biotechnological Revolution".

In the currently promising situation for soybeans, among the various agrotechnological questions being considered, the focus is now on production in the interval between the main summer crops, the so-called second crop ("out season"), with the principal aim of obtaining seeds for sowing in the main summer crop ("main season"). However, there is little technical knowledge on soybean cultivation for the second crop since, apart from a few empirical observations by farmers in south Brazil and some savanna areas, few research data are available.

Due to the ecophysiological characteristics of soybeans, such as its water, temperature and photoperiodic needs, more studies are necessary which can develop a suitable agroclimatic zoning for second crop soybeans. These studies would recommend more suitable sowing periods for producing quality seed in the necessary quantities, as well as the selection of genotypes with greater stability-adaptability. Crop management systems must also merit careful attention, since exposed to a differentiated climate when grown as a second crop, adaptations, such as for disease control (e.g. soybean rust), need to be optimized. Irrigation management is another extremely important issue, especially for a second crop in the savanna region, because soybeans may suffer from drought during the reproductive stages.

Second crop soybeans in a crop rotation system can be an extremely valid strategy because it is a legume (with efficient nitrogen fixation) planted in the period between the main summer crops. The use of systems in some savanna areas, such as centre pivot irrigation, should also be mentioned. However, sowing periods should respect the present legislation, which limits cultivation during certain periods, through the mandatory no-planting period ("vazio sanitário").

If the real possibility of lower temperatures and low humidity during the maturation and harvesting of a second crop in southern areas of Brazil, and at high altitudes in the Brazilian savannas, are considered, this would be a significant alternative for obtaining healthy seeds with a high physiological quality. Although many farmers have actually been planting a second crop, there are still no consistent results published in the literature which definitively support this possibility. The opportunity to preserve genetic quality through a reduction of gene flow in the second crop should be mentioned, and this is beneficial considering the introduction of GMO.

As well as potentially supplying seed with the desired quality, seed production in the second crop can also use the available infrastructure for cleaning and storing seed, thus reducing its idleness. Seed produced by the second crop would also satisfy much of the regional demand, be stored for less time, subject to fewer quality losses and add value to the productive system of many rural businesses.

In conclusion, second crop soybeans show theoretical and real advantages, which need to be more carefully evaluated. Second crop cultivation, therefore, is valid but still requires to be fully confirmed by agronomical studies.

5. References

ALBRECTH, L.A. 2009. Tese (Doutorado) - Universidade Estadual de Maringá, Maringá, 2009.100p.

ABRASEM - ASSOCIAÇÃO BRASILEIRA DE SEMENTES E MUDAS. Anuário ABRASEM 2010. Brasília, 2010. 80p.

AHRENT, D.K.; CAVINESS, C.E. Natural cross-pollination of twelve soybean cultivars in Arkansas. Crop Science, v.34, p.376-378, 1994.

ÁVILA, M.R.; BRACCINI, A.L.; MOTTA, I.S.; SCAPIM, C.A.; BRACCINI, M.C.L. Sowing seasons and quality of soybean seeds. Scientia Agricola, Piracicaba, v.60, n.2, p. 245-252, 2003.

BARNI, N.A.; BERGAMASCHI, H. Alguns princípios técnicos para a semeadura. In: MIYASAKA, S.; MEDINA, J.C. (Ed.). A soja no Brasil. São Paulo: ITAL, 1981. p. 476-480.

BEWLEY, J. D.; BLACK, M. Seeds: physiology of development and germination. 2. ed. New York: Plenum Press, 1994.

BOERMA, H.R.; MORADSHAHI, A. Pollen movement within and between rows to male-sterile soybeans. Crop Science, v.15, p.858-861, 1975.

BORÉM, A. Escape gênico: os riscos do escape gênico da soja no Brasil. Biotecnologia, Ciência e Desenvolvimento, v.10, p.101-107, 1999.

BRACCINI, A.L.; STÜLP, M.; ALBRECHT, L.P.; ÁVILA, M.R.; SCAPIM, C.A.; RICCI, T.T. Agronomic traits and seed yield produced in the soybean-corn crop in succession cropping. Acta Scientiarum. Agronomy, Maringá, v.32, n.4, p.651-661, 2010.

CÂMARA, G.M.S. Efeito do fotoperíodo e da temperatura no crescimento, florescimento e maturação de cultivares de soja (Glycine max (L.) Merrill). 1991. Tese (Doutorado) - Universidade Federal de Viçosa, Viçosa, 1991.

CASARIN, D. P.; KOUSKY, V. E. Anomalias de Precipitação no Sul do Brasil e Variações na Circulação Atmosférica. Revista. Brasileira. Meteorologia, v. 1, p. 83-90, 1986.

CÉLERES. Relatório biotécnologia. Uberlândia, MG. 7p.

CHRISTENSEN, C.M. Microflora and seed deterioration. In: ROBERTS, E.H. (Ed.). Viabiliby of seeds. Syracuse: Syracuse University Press, 1972. p.59-93.

CONAB. Soja - Brasil: série histórica de área plantada, produtividade e produção: safras 1976 a 2009/2010 em mil hectares. Brasília, 2010. Disponível em: <http://www.conab.gov.br/conteudos.phpa=1252&t=&Pagina_objcmsconte>. Acesso em: 10 set. 2010.

COSTA, N.P.; FRANÇA NETO, J.B.; HENNING, A.A.; KRZYZANOWSKI, F.C.; CABRAL, N.T.; MENDES, M.C. Efeito da época de semeadura sobre a qualidade fisiológica de sementes de soja no Estado do Mato Grosso. Revista Brasileira de Sementes, v.17, n.1, p.107-112, 1995.

DALLACORT, R.; FREITAS, P. S. L.; GONÇALVES, A. C. A.; FARIA, R. T.; REZENDE, R.; BERTONHA, A. Níveis de probabilidade de rendimento de quatro cultivares de soja em cinco datas de semeadura. Acta Scientiarum. Agronomy, v. 30, n. 2, p. 261-266, 2008.

DELOUCHE, J.C. Physiological changes during storage that affect soybean seed quality. In: SINCLAIR, J.B.; JACKOBS, J.A. (Ed.). Soybean seed quality and stand establishment. [S.l.]: Intsoy, 1982. p.57-66. (Intsoy, 22).

EMBRAPA. Tecnologias de produção de soja: região central do Brasil – 2008. Londrina: Embrapa Soja; Embrapa Cerrados; Embrapa Agropecuária Oeste, 2008. (Sistemas de Produção, 12).

EMBRAPA. Tecnologias de produção de soja: Paraná – 2006. Londrina: EMBRAPA Soja, 2005. 208p. (Sistemas de Produção, 8).

ERICKSON, E.H.; BERGER, G.A.; SHANNON, J.G.; ROBBINS, J.M. Honey bee (Hymenoptera-Apidae) pollination increases soybean yields in Mississippi Delta region of Arkansas and Missouri. Journal of Economic Entomology, v.71, p.601-603, 1978.

FOX, G., TURNER, J., GISLLESPIE, T. The value of precipitation forecast infomation in winter wheat production. Agricultural and Forest Meteorology, v.95, 99-111, 1999.

HENNING, A.A. Testes de sanidade de sementes de soja. In: SOAVE, J.; WETZEL, M.M.V.S. (Ed.). Patologia de sementes. Campinas: Fundação Cargill, 1987. p.441-454.

HENNING, A.A.; FRANÇA NETO, J.B. Effect of *Phomopsis* spp on soybean seed quality in Brazil. In: Conference on the *Diaporthe/Diaporthe* diase complex of soybean. Fort Walton Beach: Proceeding Springfield, 1984. p.66-67.

LEAL, L. S. M.; SILVA, M. M.; SANTOS, S. N. M.; MORAES, M.; NETO, O. B.; Análise do Balanço Hídrico e Aptidão Agroclimática para o Cultivo de Soja no Sul do Estado do Pará. In: XII CONGRESSO BRASILEIRO DE AGROMETEOROLOGIA E III REUNIÃO LATINO-AMERICANA DE AGROMETEOROLOGIA, 2001, Fortaleza. Anais..., 201-202p.

MACHADO, J.C. Patologia de sementes: significado e atribuições. In: CARVALHO, N.M.; NAKAGAWA, J. (Coord.). Sementes: ciência, tecnologia e produção. 3. ed. Campinas: Fundação Cargill, 1988. 424p.

MARCOS FILHO, J. Fisiologia de sementes de plantas cultivadas. Piracicaba: FEALQ, 2005. 495p.

MARCOS FILHO, J.; CARVALHO, R.V.; CÍCERO, S.M.; DEMÉTRIO, C.G.B. Qualidade fisiológica e comportamento de sementes de soja (*Glycine max* (L.) Merrill) no armazenamento e no campo. Anais da Escola Superior de Agricultura "Luiz de Queiroz", Piracicaba, v.42, p.195-249, 1985.

MARCOS FILHO, J.; GODOY, O.P.; CÂMARA, G.M.S. Tecnologia da produção. In: CÂMARA, G.M.S. et. al. Produção, pré-processamento e transformação agroindustrial. São Paulo: Secretaria da Indústria, Comércio, Ciência e Tecnologia, 1982. p. 01-39.

MARTINS, M.C.; CÂMARA, G.M.S.; PEIXOTO, C.P.; MARCHIORI, L.F.S.; LEONARDO, V.; MATTIAZZI, P. Épocas de semeadura, densidade de plantas e desempenho vegetativo de cultivares de soja. Scientia Agricola, v.56, n.4, p. 851-858, 1999.

MIRANDA, M.A.C.; MASCARENHAS, H.A.A.; TURATTI, J.M.; RAMIRO, Z.A. Programa integrado de pesquisa de soja. São Paulo: Secretaria da Agricultura e Abastecimento/Coordenadoria de Pesquisa Agropecuária, 1986. 17p.

MOTTA, I.S.; BRACCINI, A.L.; SCAPIM, C.A.; INOUE, M.H.; ÁVILA, M.R.; BRACCINI, M.C.L. Época de semeadura em cinco cultivares de soja. II. Efeito na qualidade fisiológica das sementes. Acta Scientiarum, v.24, n.5, p.1281-1286, 2002.

NAKAGAWA, J.; MACHADO, J.R.; ROSOLEM, C.A. Efeito da densidade de plantas e da época de semeadura na produção e qualidade de sementes de soja. Revista Brasileira de Sementes, v.8, n.3, p.99-112, 1986.

NAKAGAWA, J.; ROSOLEM, C.A.; MACHADO, J.R. Épocas de semeadura da soja. I. Efeitos na produção de grãos e nos componentes da produção. Pesquisa Agropecuária Brasileira, v.18, n.11, p.1187-1198, 1983.

NAKAGAWA, J.; ROSOLEM, C.A.; MACHADO, J.R. Desempenho de sementes de soja originárias de culturas estabelecidas em diferentes épocas. Revista Brasileira de Sementes, v.6, n.3, p.61-76, 1984.

NELSON, R.L.; BERNARD, R.L. Production and performance of hybrid soybeans. Crop Science, v. 24, p.549-553, 1984.

OLIVEIRA, A.; SADER, R.; KRZYZANOWSKI, F.C. Danos mecânicos ocorridos no beneficiamento de sementes de soja e suas relação com a qualidade fisiológica. Revista Brasileira de Sementes, v. 21, n. 1, p.59-66, 1999.

PAOLINELLI, G. de P.; TANAKA, M.A. de S.; REZENDE, A.M. de. Influência da época de semeadura sobre a qualidade fisiológica e sanitária de sementes de soja. Revista Brasileira de Sementes, v.6, n.1, p.39-50, 1984.

PASCHAL II, E.H. & ELLIS, M.A. Variation in seed quality characteristics on tropically grown soybeans. Crop Science, v.18, n.3, p.837-40. 1978.

PEIXOTO, C.P.; CÂMARA, G.M.S.; MARTINS, M.C.; MARCHIORI, L.F.S.; GUERZONI, R.A.; MATTIAZZI, P. Época de semeadura e densidade de plantas de soja: I. Componentes da produção e rendimento de grãos. Scientia Agrícola, v.57, n.1, p.89-96, 2000.

PEREIRA, L.A.G.; COSTA, N.P.; QUEIROZ, E.F.; NEUMAIER, N.; TORRES, E. Efeito da época de semeadura sobre a qualidade de sementes de soja. Revista Brasileira de Sementes, v.1, n.3, p.77-89, 1979.

PEREIRA, E.B.C.; PEREIRA, A.V.; FRAGA, A.C. Qualidade de sementes de cultivares precoces de soja produzidas em três épocas. Pesquisa Agropecuária Brasileira, v.35, n.8, p., 2000.

POPINIGS, F. Fisiologia da semente. 2. ed. Brasília: AGIPLAN, 1985. 289p.

FEHR, W.R.; CAVINESS, C.E.; GURMOOD, D.T.; PENNINGTON, J.S. Stage of development description for soybean, *Glycine max* (L.) Merrill. Crop Science, v.11, n.6, p.929-931, 1971.

FRANÇA NETO, J.B.; HENNING, A.A. DIACOM: diagnóstico completo da qualidade da semente de soja. Londrina: EMBRAPA Soja, 1992. 21p. (Circular Técnica, 10).

FRANÇA NETO, J.B.; HENNING, A.A. Qualidade fisiológica e sanitária de sementes de soja. Londrina: EMBRAPA Soja, 1984. 39p. (Circular Técnica, 9).

ROBERTS, E.H. Loss of viability and crop yields. In: ROBERTS, E.H. (Ed.). Viability of seeds. London: Chapman and Hall, 1974. p.307-320.

SANTOS, T. L. Soja. In: CASTRO, P. R. C.; KLUGE, R. A.; SESTARI, I. Manual de fisiologia vegetal: fisiologia dos cultivos. Piracicaba: Agronômica Ceres, 2008. p. 157-175.

SEDIYAMA, T.; CARDOSO, A.A.; VIEIRA, C.; ANDRADE, D. Taxa de hibridação natural em soja, em Viçosa e em Capinópolis, Minas Gerais. Revista Ceres, v.2, p.329-331, 1970.

SEDIYAMA, C.S.; VIEIRA, C.; SEDIYAMA, T.; CARDOSO, A.A.; ESTEVÃO, H.H. Influência do retardamento da colheita sobre a deiscência das vagens e sobre a qualidade e poder germinativo das sementes de soja. Experientiae, v.14, n.5, p.117-141, 1972.

TEKRONY, D.M. Effect of date of haverstmaturity on soybean seed quality and *Phomopsis* sp. seed infection. Crop Science, v.24, n.1, p.189-193, 1984.

TEKRONY, D.M.; EGLY, D.B.; PHILLIPS, A.D. Effects of field weathering on the viability and on vigor of soybean seed. Agronomy Journal, v.72, n.5, p.749-753, 1980.

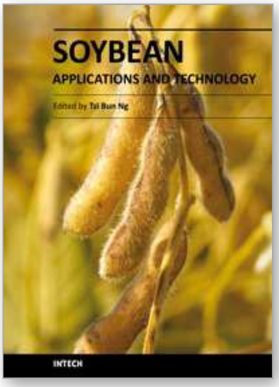
TRAGNAGO, J.L.; BONETTI, L.P. Diferentes épocas de semeadura no rendimento e outras características de alguns cultivares de soja no Rio Grande do Sul. In: SEMINÁRIO NACIONAL DE PESQUISA DE SOJA, 3., 1984, Campinas. Anais… Londrina: EMBRAPA/CNPSo, 1984. p.57-69.

VAL, W.M.C.; GAUDENCIO, C.A. & GARCIA, A. Ensaio sobre época de plantio. In: Resultados da pesquisa de soja, 1984/85. Londrina: EMBRAPA-CNPSo, 1985. p.393-396.

VERNETTI, F.J.; BONATTO, E.R.; TERASAWA, F.; GASTAL, M.F. Observações sobre a taxa de cruzamentos naturais em soja, em Pelotas e Sertão, RS e Ponta Grossa, PR. Ciência e Cultura, v.1, p.36-41, 1972.

RAY, J.D.; KILEN, T.C.; ABEL, C.A.; PARIS, R.L. Soybean natural cross-pollination rates under field conditions. Environmental Biosafety Research, v.2, p.133-138, 2003.

YORINORI, J.T. Doenças da soja no Brasil. In: Fundação Cargill. Soja no Brasil Central. Campinas : Fundação Cargill, 1986. p.301-363



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Soybean is an agricultural crop of tremendous economic importance. Soybean and food items derived from it form dietary components of numerous people, especially those living in the Orient. The health benefits of soybean have attracted the attention of nutritionists as well as common people.