International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-12; Dec, 2021
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.812.20

The sanitary void of soybeans as a measure to control Asian rust and the importance of official plant health defense actions in this context

Sílvia Vollino Libman Luft[1], Emerson Shirota[1], Carlos Eduardo Bitencourt Cardozo[1], Carlos Matheus de Souza Sobrinho[1], Cristiane Navarrete Néris[1], Danilo Furtado dos Santos[1], Luís Felipe Charbel[1], Nelson Caleffi Del Corona[1], Kelcilene Azambuja Martinez[1], Pedro Kadjaoglanian M Molina[1], Samuel Carvalho de Aragão[2], Jorge Granja de Oliveira Junior[1], Márcio Teixeira Oliveira[3], Sônia Maria Salomão Arias[4], Gisele Garcia de Sousa[1], Paulo Eduardo Ferlini Teixeira[5], Matheus Bornelli de Castro[2], Bruno Toríbio Lima Xavier[2], Priscila Gonzales Figueiredo[2]

[1]State Agency for Animal and Plant Sanitary Defense - IAGRO, Campo Grande-MS, Brazil
[2]Federal Institute of Education, Science and Technology of Mato Grosso do Sul - IFMS, Campus Naviraí-MS, Brazil
[3]Federal Institute of Education, Science and Technology of Mato Grosso do Sul - IFMS, Campus Três Lagoas-MS, Brazil
[4]Ministry of Agriculture, Cattle and Supplying - MAPA, Campo Grande-MS, Brazil
[5]Federal Institute of Education, Science and Technology of Mato Grosso do Sul - IFMS, Campus Nova Andradina-MS, Brazil
Corresponding Author Email : silvia_vollino@hotmail.com

Received: 01 Oct 2021,
Received in revised form: 28 Nov 2021,
Accepted: 10 Dec 2021,
Available online: 16 Dec 2021

***Keywords*—IAGRO, Mato Grosso do Sul, Sanitary Empty, Soy.**

***Abstract*—** *In Mato Grosso do Sul agribusiness accounts for 30% of gross domestic product - GDP, being the 5th largest soybean producer in the country and the 4th in corn production. According to the state government, the 2020/21 soybean crop exceeded forecasts and reached 13.305 million tons, a volume 17.8% higher than that of the 2019/2020 crop. Asian rust is one of the diseases that most affect and compromise soybean production. The causative agent is the fungus Phakopsora pachyrhizi, which is biotrophic, polycyclic and has a large amplitude of hosts, which gives it the ability to survive from one agricultural year to another, due to "green bridges". Asian rust, which was rapidly softened every year, was so severe in the 2005/2006 crop that there was a mobilization among those involved in the production chain, to try to standardize the activity and reduce the problem in the following harvests. This joint effort, with forums and meetings, came the creation of a state legislation based on the prevention and control of Asian Soybean Rust in Mato Grosso do Sul. Its initial milestone was State Law No. 3,333, of December 21, 2006, whose purpose was to implement the sanitary void of soybeans and make it mandatory to control raccoon plants after harvest. To make the effects of the sanitary void more effective, State Law No. 5025, of July 19, 2017, prohibited the cultivation of soybeans after*

soybeans, in the same area and in the same agricultural year. Then, the Secretary of State for The Environment, Economic Development, Production and Family Agriculture - SEMAGRO published Resolution SEMAGRO No. 648, from August 15, 2017, establishing the soy sowing calendar from September 16 to December 31. In order to characterize the plant health defense actions related to the supervision and application of legislation dealing with the sanitary void, for the purpose of maintaining the control of Asian soybean rust in the State of Mato Grosso do Sul, it was carried out the survey of information of inspection actions with the state agency, from 2009 to 2021, stored in the IAGRO database. The information showed that, after the soybean sanitary void law, fiscalization and sanitary education work positively influenced compliance with the legislation and few producers deliberately violated it, especially with regard to sowing during the sanitary void period. The greatest number of infringements was due to the lack of registration of the planting areas, followed by the non-control of spontaneously growing soybean plants.

I. INTRODUCTION

Brazil is one of the main exporters of agricultural products in the world, serving more than 180 countries, having as main buyers China, MERCOSUR countries, the European Union and the United States. The main exportsegments of products from Brazilian agribusiness are the soybean complex (36.9% share); meat (19.2% share); forest products (11.5% share); cereals, flours and preparations (8.6% share) and sugar-alcohol complex (8.4% share), which had an 84.5% share in the total exports of August 2021 [1].

It should be noted that all agricultural production is carried out in about 30% of the Brazilian territory, being only 7.8% for agriculture as a whole and only 4% destined for soybean planting [2], which proves the country's commitment to sustainable production and environmental preservation.

In Mato Grosso do Sul, in 2018, agribusiness accounted for 30% of gross domestic product – GDP, constituting the main segment of the state's economy[3]. In 2020, the state's Gross Production Value – VBP increased by 29%, reaching R$70.9 billion. The State is the 7th in the Brazilian agribusiness production ranking and agriculture has been standing out year by year. While the VBP of livestock production totaled R$ 17.7 billion in 2020 and grew 14% compared to 2019, the VBP of crops increased by 34.4% in this period, reaching R$ 53 billion[4].

Soybean is grown throughout the state of Mato Grosso do Sul, except for the Pantanal biome region, with emphasis on the northern region (Chapadão do Sul) and the southern region of the state (Maracaju, Dourados). However, there has been an advance in grain planting areas in some traditionally livestock regions, in which soybean areas have been increasing in place of pasture areas, especially where they present some degree of degradation [4].

Asian rust is one of the diseases that most affect and compromise soybean production, which can cause losses of up to 90% in untreated areas [5]. In the 2001/2002 crop, Asian rust reached about 60% of the Brazilian soybean area. In Mato Grosso do Sul, São Gabriel d'Oeste, Chapadão do Sul and Costa Rica were the most affected municipalities, recording income losses ranging from 30 to 75% in the last two [6].

The severity of the disease in the 2005/2006 harvest was aggravated by two causes: favorable climatic conditions, which allowed the early emergence of the disease, still in the vegetative stage and also by control failures, because the applications were timed, starting in flowering, but delayed to that context [7]. The severe situation caused those involved in the soybean production chain to mobilize to seek the standardization of the activity and reduce the problem in the following harvests. This joint effort, with forums and meetings, came the creation of State Law No. 3,333, of December 21, 2006, based on the prevention, control and eradication of Asian Soybean Rust in Mato Grosso do Sul.

The main pillar of this law is the control of soybean sowing, which in Mato Grosso do Sul, is allowed soon after the end of the soybean sanitary void, and the sowing calendar from September 16 to December 31, is established, according to SEMAGRO Resolution no. 648, from August 15, 2017.

Thus, this study had as general objective to characterize the actions carried out by IAGRO in relation to the sanitary void of soybean in the control of Asian rust.

a) Origin, domestication and dissemination of soybeans in the world

The oldest literary reference about soy would be the one contained in the Pen Ts'ao Kang Mu herbarium, written by the Chinese Emperor Sheng Nung, in imprecise date, between the years 2838 and 2383 BC. However, Chang & Watson (no / d) cited by Bonetti (1981), suggest that only dates recorded in history after 814 AD are accepted as the most correct [8]. According to Hymowitz (1976), the emergence of soybeans as a domestic plant took place in the 19th century. XI BC., in the northern half of China, which is the main center of origin of the species and assumed that the first crops occurred during the Shang Dynasty, between 1500 and 1027 BC. From the 17th century to the 19th century, it was introduced in several countries and was taken from Japan to Europe (1712). In the United States it was introduced in 1804, where it acquired importance only in the year 1880, as forage. In 1890, many experimental agricultural stations had experiments with soybeans, but it was only in 1941 that there was significant expansion of the area for grain production in that country.In Brazil, according to the history established by Bonato & Bonato (1987), soybeans were initially brought to Bahia in 1882 for varietytesting. In 1892, the first studies were initiated in São Paulo, at the Agronomic Station of Campinas (current IAC). In Rio Grande do Sul, in 1901, the first performance data of the species were obtained, but the official introduction of culture in the State is attributed to Professor F. G. Graig, from the School of Agronomy and Veterinary Of the Technical University (now UFRGS), in 1914. Only between 1946 and 1950, variety crops were started for behavior observation in several regions of Brazil: PR, SP, MG and RS.

Outside the experimental fields, the first plantations for consumption in food were made in 1908 by Japanese immigrants in the State of São Paulo [8]. Soybean cultivation on a commercial scale began in Rio Grande do Sul in 1941, the year also of the construction of the first soybean processing plant. Initially, the cultivation aimed at the production of forage and grains for the rooting of pigs. With the expansion of crops, in 1949 the first export of Brazilian soybeans occurred, of about 18,000 tons, when Brazil began to appear in international statistics as a soybean producer[11].

b) The expansion of soybean cultivation to the Midwest and North of the country

In the late 1960s, commercial soybean production became a strategic necessity. The country intended to increase the production of pigs and poultry, generating demand for soybean meal. Soybean planting then emerged as a summer option in succession to wheat. In the early 1970s more than 80% of the volume produced was concentrated in the three states of the Southern Region. During this period, the valorization of soybeans in the international market sharpened the attention of farmers and the Brazilian government [1] and the expansion of the crop became of interest to both.

Given the different edaphoclimatic conditions of the country, the pioneering spirit of the producers and the possibility of expanding the cultivated area in Brazil, with the leadership of the Brazilian Agricultural Research Company - EMBRAPA and participation of several universities and private companies, there were investments in technological research in several areas of agronomy such as: genetic improvement, agrometeorology, fertility and land use, phytosanitary defense, etc. to adapt culture to the various Brazilian conditions and ecosystems.

According to FERREIRA and SILVA (2019), in the late 1970s the Brazilian Midwest was considered a barn of opportunities for the expansion of the agricultural frontier and many factors encouraged migration from the south to the west center of the country. The land was low cost, had good conditions of relief, flat in large part, and well-defined dry and rainy weather. And also the special credit lines that were opportunistic by the Government, facilitated investments. This encouraged the occupation of large "empty spaces" in central Brazil, although the lands had yet to be cleared, demanding a lot of persistence, determination and a lot of work.

Thus, the Midwest emerged as a new productive option as research in the area of soils and fertility, mechanization and genetic improvement of soybeans intensified, seeking cultivars more adapted to the conditions of the cerrado, previously considered a poor soil, but which came to be seen with a new look. From the constant insertion of technology making the soil fit for the practice of agriculture, allied to a geopolitical condition that favors production, the Midwest has achieved, each year, increasingly higher production rates [14].

The achievement of good results of the research provided and continues to provide the expansion of the agricultural frontier to the northern region of the country (Fig. 1) and excellent productivity.

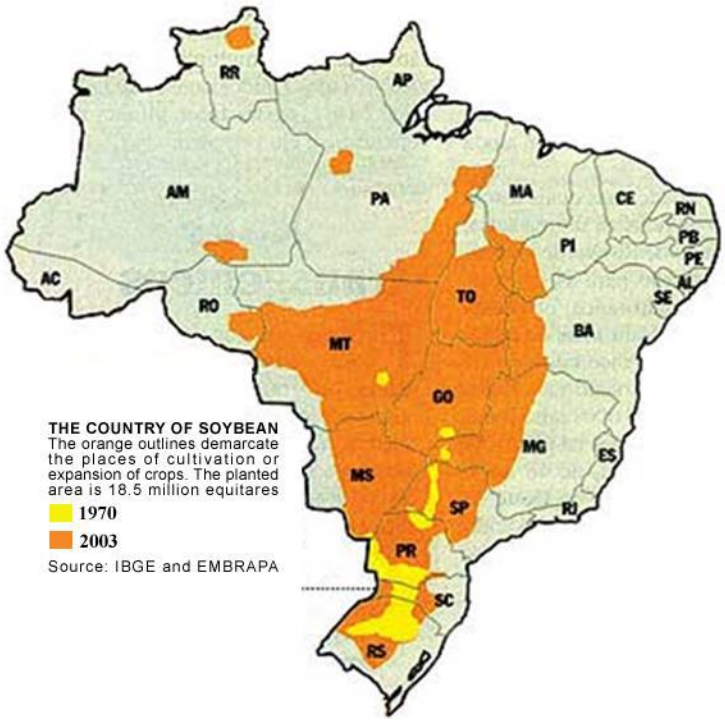

Fig. 1: Expansion of the soybean plantation area in Brazil from 1970 to 2003.

Source: Agrolink-a, (2021).

c) Soybeans in the State of Mato Grosso do Sul

The expansion of agricultural areas in Brazil and, mainly, soybean cultivation in the Midwest, was consolidated as a result of stimuli and economic advantages combined with the warming of the international market [12]. An advantage for the State of Mato Grosso do Sul in the process of geographical expansion for soybean production, towards the Cerrado, were the large dimensions of the land, as evidenced by Faccin (2017) and Ferreira & Silva (2019), when presenting the fact as one of the variables involved in the regional competitiveness of the State. Thus, the structuring and specialization of the south-mato-grossense territory occurred in order to meet the demand of the sojicultorsector[12][15].

In Mato Grosso do Sul, the significant increases in the production of the soybean agro-industrial complex are the result of the agricultural modernization acquired in recent decades [16]and soybean production, in the last 20 years, has grown 320%, keeping the state in the position of 5th largest producer of grain in the country [17]. Thus, soybeans play a major role in the command of territorial structuring, with the production of large-scale agricultural commodities for export as the economic base of the State[12].

In Brazil, exports of basic products from the primary sector (fig. 2), with little or no added value, such as those of the soybean complex (crushed soybean and soybean oil meal and residues), represented 11.9% of the value of the products exported by the country in 2018. Similarly, the exporting matrix of the stateof Mato Grosso do Sul (fig. 3), compared to exports from Brazil, it portrays the same composition, in which soy complex products occupied the first position, with 37.4 % of the value of exportedproducts [18].

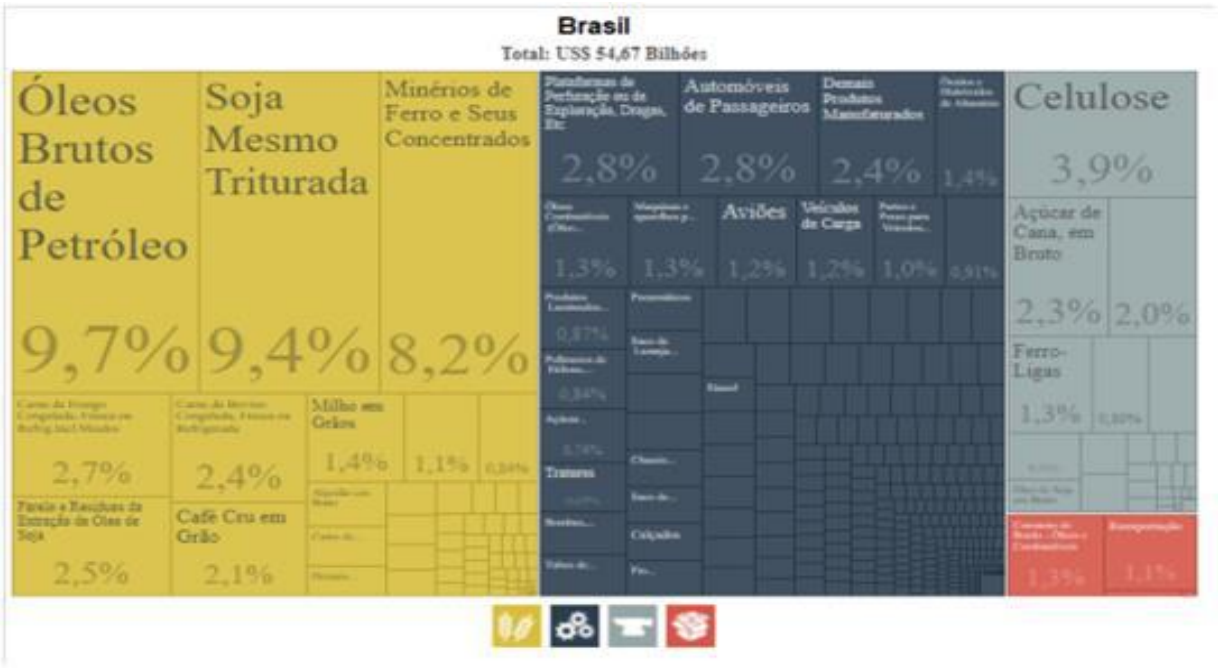

Fig. 2: Overview of exported products: participation in relation to the value exported in 2018.

Source: Comex Vis/MDIC Reproduction (2019).

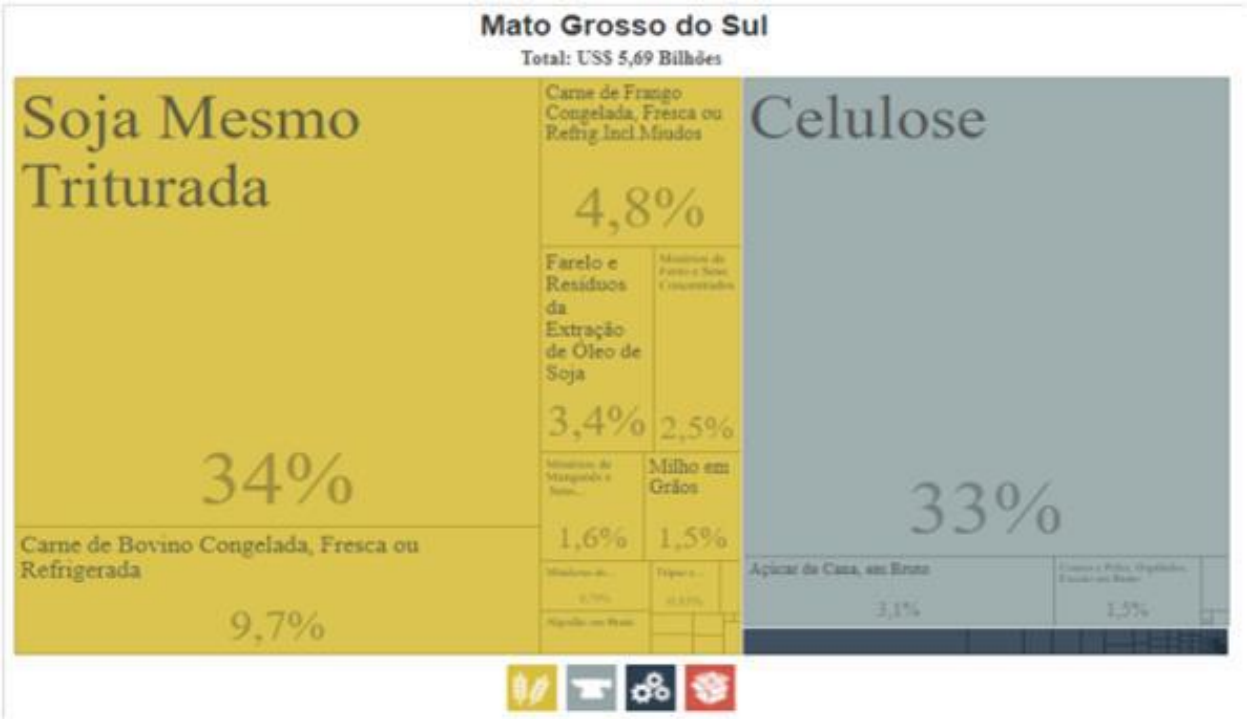

Fig. 3: Mato Grosso do Sul: Overview of products exported in 2018.

Source: Comex Vis/MDIC Reproduction (2019).

The soybean chain is among the activities that form the basis of the South Mato Grosso economy, contributing to the maintenance of the industry sectors and also the services derived from primary products, created for the implementation of the few main activities.

The use of precision technology in agriculture combined with rural management comes year after year,

providing increased productivity. Agricultural research in Mato Grosso do Sul generates technologies that, when incorporated into production systems, ensure their viability, with consistent technological bases [19].

According to data from SEMAGRO (2021), in Mato Grosso do Sul, in the 2020/21 harvest soybean production reached an all-time high, when 13,305 million tons of soybeans were produced in an area of 3,529 million hectares[17]. The productivity of 62.8 bags/ha exceeded expectations and the volume produced was 17.8% higher than that harvested in the previous harvest, which contrasts with the increase of only 4% in the planted area. Among the municipalities with little agricultural tradition and which has been growing in the planted area of soybeans, are Campo Grande and Bandeirantes (fig. 4), these in recent years, have replaced pastures, mostly presenting some degree of degradation, by the cultivation of legumes. Also other municipalities, besides those already mentioned, such as Jaraguari, Camapuã, Itaquiraí, Paraíso das Águas, Nova Andradina, Anaurilândia, Naviraí and Ribas do Rio Pardo are having their cultivated areas significantly increased[19].

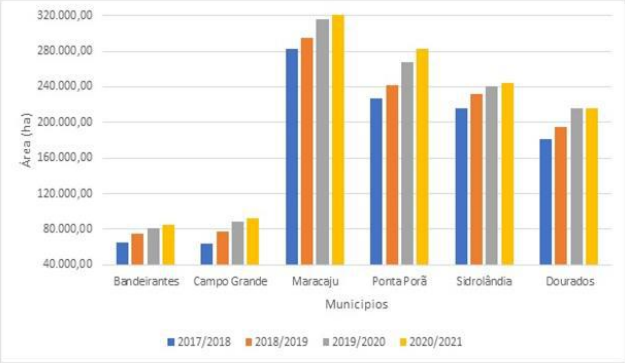

Fig. 4: Evolution of soybean cultivated area in some municipalities of Mato Grosso do Sul.

Source: CONAB, 2021

d) State Agency for Animal and Plant Sanitary Defense - IAGRO

With the creation of the State of Mato Grosso do Sul in 1977, it was necessary to implement the inspection and health defense service in the new state and then, under Decree-Law No. 9 of January 1, 1979, the Department of Agricultural Inspection and Defense of Mato Grosso do Sul - IAGRO was created. Subsequently, through Law No. 2,152, of October 26, 2000, the agency received the current name: State Agency for Animal and Plant Sanitary Defense, maintaining the old acronym.

IAGRO is an autarchy, with its head and fore in the State Capital. It is bound by the Secretary of State for The Environment, Economic Development, Production and Family Agriculture - SEMAGRO, which, according to Law No. 4,640 of December 24, 2014, is the body responsible for supervising the activities of the Agency, which has legal personality of public law, own assets, technical, administrative and financial autonomy, and indefinite duration, under the law, being the body responsible for operationalizing and implementing the standards of the Unified System of Attention to Agricultural Health - SUASA.

Purposes of the State Agency for Animal and Plant Sanitary Defense:

> *1.Implement public policies in the areas of inspection, inspection, health education and health, with the objective of promoting, maintaining and recovering animal and plant health, the quality of its products and by-products, through health defense, control, inspection and inspection of products and by-products of agricultural origin, inspection of agricultural products and biosafety activities, to ensure human health.*
>
> 2. *Comply with and enforce the obligations delegated by the Executive Branch, with regard to legislation governing the protection of animal and plant health and the control and inspection of agricultural products, goods and services, processes and technologies achieved by the system of attention to agricultural health.*

IAGRO is the agricultural defense authority of the State of Mato Grosso do Sul and prioritizes promoting, maintaining and recovering the health of animals and vegetables, as well as the quality of agricultural products, their derivatives, especially in relation to harmlessness, acting in prevention with a view to quality and the defense of the diffuse rights of consumers. Decree No. 15,519, of October 14, 2020, assures IAGRO the other prerogatives necessary for the proper exercise of its duties.

In addition to implementing actions to meet mapa's federal programs, it also implements actions not covered by these programs, but which are of strategic and economic importance to the state, due to the need to preserve public health, animal and plant health, or due to compliance with rules established by international organizations such as the OIE, CIPV and Codex alimentarius, or to meet the demands of the Public Prosecutor's Office.

IAGRO's work in relation to agricultural production goes beyond inspection, surveillance and inspection. From these actions, problems and failures in the productive system are often found that can harm both the health of the general population, as well as the finances of producers,

municipalities and the state. As an example is the recent introduction in south-mato-grossense territory of the bacterium causing HLB disease in citrus and cases of misuse of pesticides, which can leave residues in food, not meeting the requirements of the PNCRC - National Plan for Control of Waste and Contaminants, harming consumers and also international trade, subjecting the country to commercial retaliation, in addition to causing damage to the environment.

Many of the problems of health defense can be minimized in the long term, provided that health education work is continuously developed that, together with the sanctions provided for in the laws governing agricultural activities, will consciously and lastingly promote a change in behavior in producers and others involved in production processes.

The work of health education and awareness carried out by IAGRO is based on the National Program of Sanitary Education in Agriculture - PNESA, created by The Normative Instruction MAPA no. 28, of May 15, 2008, meeting the other national health defense programs of MAPA and other topics of interest to health defense, in order to bring preventively to the target public the technical knowledge and requirements of sanitary legislation, in order to make you aware of the production of safe food. Educational actions are developed, assuming that all those involved in production processes should be aware of their responsibility in relation to animal and plant health defense and the use of agricultural insumuins.

e) Characterization of soybean rust and its occurrence in Brazil, the Midwest and Mato Grosso do Sul

Asian rust, caused by the fungus Phakopsora pachyrhizi, is among the main diseases of soybeans and has greater potential for crop damage in the country. Early defoliation is the main damage caused by Asian rust, which causes a decrease in photosynthetic and photonatorates, preventing the complete formation of grains, with consequent reduction of productivity [20].

The level of damage that the disease reaches and the damage caused will depend on what stage of growth the plants are in when the fungus begins the colonization of leaf tissues and also that the climatic conditions are favorable to the multiplication of the pathogen, which can reach 70% [16]. In studies conducted by Sumitomo Chemical Brasil (2021)[5], it was found that, if not controlled, because it is an aggressive microorganism, Asian rustcan cause losses of up to 90% in soybean crops.

At any stage of development, soybean plants can be infected by Asian rust, but the fungus attack becomes more intense from the closure of the crop canopy, when the highest incidence is observed due to the formation of a microclimate favorable to infection. Shading and higher humidity are factors that give protection to spores against the effects of UV radiation and direct solar radiation, which have a deleterious effect on their survival [21].

The onset of the disease occurs when uredospores (spores) germinate and begin colonization in the host tissues. The first symptoms are the appearance of tiny dark scores (1 mm), greenish to greenish-gray on the leaf. With the evolution of the disease, lesions (2 to 5 mm) of light brown color with darkened spots appear. On the abaxial face of the leaves are the uredias (breeding structure), which break and release the uredospores, which are transported by the wind and which restart the cycle [20]. After infection by the fungus, the leaves become chlorotic, dry and early dehiscence occurs. This will impact the photosynthetic rate, which will be lower. Therefore, the earlier there is infection and defoliation, the smaller the size of the grains with greater loss of yield and quality [22].

The first record of Asian rust in Brazilian crops occurred in 2001, in Paraná, from there, in the following harvests, it spread throughout the other producing regions. The evolution of the disease throughout Brazil was very rapid and in the 2001/2002 harvest, it reached about 60% of the Brazilian soybean area, according to a study by Yorinori et al. (2005) cited by Godoy et al. (2020) [21]. In this harvest, in Mato Grosso do Sul the most affected municipalities were: São Gabriel d'Oeste, Chapadão do Sul and Costa Rica with a record of income losses ranging from 30% to 75% in the last two [6].

Characteristics of the pathogen are very important in the maintenance and persistence of the disease. According to Hartman et al. (2015) and Godoy et al. (2016), mentioned by Godoy et al. (2020), the reproductive structures of the fungus are miniature and easily disseminated by the wind. In addition, the presence of soybeans for most of the year in the producing regions that have a favorable climate for the development of the disease, were essential for the rapid expansion of Asian rust in Brazil[21]. In this sense, Yorinori et al. (2004) stated that soybean cultivation in the off-season (June/July) led to the early onset of the disease in the 2003/2004 crop, mainly in the Midwest and North regions of Brazil, being detected in 2004 in all soybean producing regions in Brazil, except in Roraima, in the Boa Vista region[6].

The vertiginous spread of the disease led to the created in 2004 the Antiferrugem Consortium, which is a network of laboratories, researchers from public and private institutions and cooperative trials for fungicide tests,

distributed in all Brazilian regions in order to monitor the occurrence and generate up-to-date information about the disease [1].

Because Asian rust is a polycyclic disease, capable of completing several cycles and spreading for long periods, it is that even after the end of the commercial harvest, the fungus continues to survive and reproduce in alternative hosts and raccoon soybean plants [5] that form the so-called "green bridge", essential for maintaining the inoculum source at high levels at the beginning of the next crop. This situation is aggravated by the cultivation of soybean scum. In Brazil, between 2006 and 2007, due to the severity of the disease and difficulty in control, which caused many problems for sojicultores, the sanitary void of soybeans (period of absence of soybeanin the field) was implanted in order to reduce the pressure of inoculum at the beginning of the following crop [23].

Data from the Antiferrugem Consortium show that in Brazil, as in the State of Mato Grosso do Sul, the number of outbreaks of the disease increased rapidly from the 2005/2006 harvest, peaking in the 2006/2007 crop (Fig. 5). On the other hand, the historical series of Asian rust records in MS shows a 4-year fall in records after the implementation of State Law No. 3,333 of December 21, 2006, establishing the sanitary void of soybeans as a tool in disease control. This makes evident the importance of phytosanitary measurement in the control of the disease, which combined with the awareness of rural producers and the use of preventive measures have achieved satisfactory results in grain production.

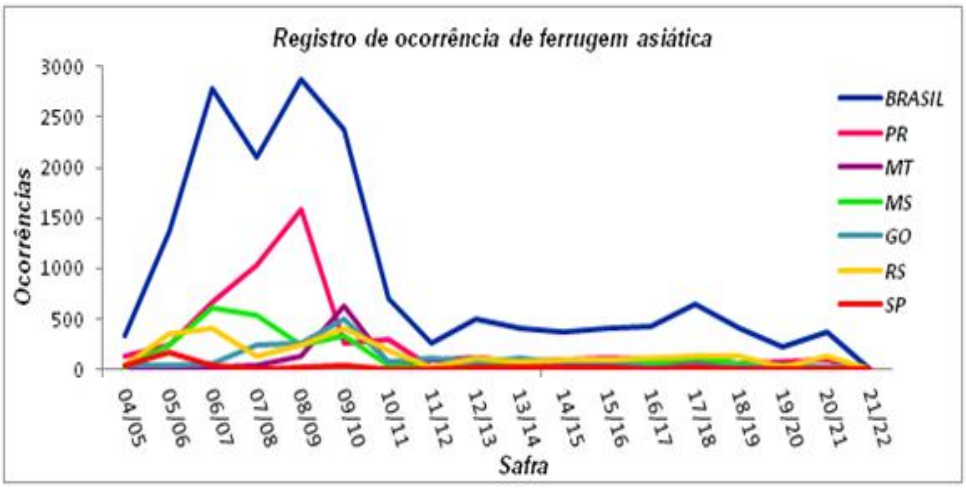

Fig. 5: Occurrences of Asian rust in Brazil. Source: Antirust Consortium/2021.

Also according to data from the Antirust Consortium, in the current crop (2021/2022), until the beginning of November, there is the report of only one focus of Asian soybean rust in the state of Roraima-RR registered in mid-September, probably due to the agricultural calendar in Roraima being different from the calendar of the rest of the country (the state is located in the northern hemisphere, in which planting usually takes place in April and June). In Brazil, in the 2020/2021 harvest, 377 foci of Asian rust were recorded, of these 25 occurred in the state of Mato Grosso do Sul.

f) Legislation applied to asian rust control

In studies conducted by Yorinori et al(2004), they found the increasing incidence and wide dissemination throughout The Brazilian territory of Asian Soybean Rust from the 2001/2002 harvest. That is why in Mato Grosso do Sul, entities linked to the sector and producers converged on the need to discipline the activity of sojiculture in theState [6].

Aiming at strengthening the agricultural production of legumes and mitigating economic risks to producers, joint phytosanitary strategies for the prevention, control and eradication of the disease were instituted through specific legislation. The strategies were supported by the research, the participation of the productive sector, representatives of the public sector and other invited relevant entities or bodies [24].

The initial milestone in Mato Grosso do Sul was State Law No. 3,333, of December 21, 2006, which established, for any areas of the state, regardless of type or location, the sanitary void of soybeans, which is the period in which there should be total absence of soybean plants, whether planted or raccoons, from 15 June to 30 September [25] date which was subsequently amended. It also determined the control of raccoon plants, those from grains abandoned

or lost in the soil at the time of harvest or during grain transport.

Another action that was implemented as mandatory for soybean producers is a declaration of soybean planting areas, which should be done annually, through registration on the IAGRO website, whose deadline was set in later law. It also stipulated that it is the responsibility of the sojicultor to always follow up during the conduction of the crop, which is the monitoring of plants for detection of the disease and realization, when due, and according to the prescriptions of its technical responsible, chemical, biological or mechanical control of prevention or fight of the disease [25].

In the same law, the State Committee for the Control of Asian Soybean Rust was created. The Committee, assertively, due to the robust technical staff, was responsible for employing dynamism to the sojiculture of the State, even though the measures it deliberated became inflexible legal instruments. Developments in agricultural production have triggered the modernisation of legislation, which can be updated over time, by appropriated legal instruments so as not to hinder rural progress [24].

The current fixed members of the Committee are: the State Agency for Animal and Plant Sanitary Defense - IAGRO; the Agrarian Development and Rural Extension Agency - AGRAER; Association of Soybean Producers of the State of Mato Grosso do Sul - APROSOJA/MS; Regional Council of Engineering and Agronomy of Mato Grosso do Sul - CREA/MS; Foundation for Agricultural Research Support of Chapadão - Chapadão Foundation; MS Foundation for Research and Dissemination of Agricultural Technologies - MS Foundation; Brazilian Agricultural Research Company - West Agricultural Research Center - EMBRAPA/CPAO [26].

On November 24, 2008, State Decree No. 12,657 entered into force, regulating State Law No. 3,333.[Later, it was necessary to make some updates of this legislation through the changes and insertions of instruments promoted by other laws. Law No. 3,606, of December 19, 2008, among other changes, instituted the socio-educational measure, which allows the conversion of the fine due to the lack of registration of planting areas participating in a lecture on the sanitary void of soybeans and relevant legislation. This law also set the period of regular registration of soybean planting areas in the state, which is from September 1 to January 10 and should be doneannually on the IAGRO website[26].

Two important changes were made by Law No. 4,218 of July 11, 2012. One was the anticipation of the end date of the sanitary void from 30 to September 15, standardizing the calendar with that of neighboring states. The other was the setting of June 14 as a date until the control of the non-control of spontaneously growing soybean plants, already mandatory by Law 3333, by the respective legal guardians, in any public or private areas where they have germinated, including rural properties, roads, warehouses, etc. and even in urban areas, and all voluntary soybean plants, must be controlled and destroyed before the start of the sanitary void [27].

The most recent complement ation was made by Law No. 5,025 of July 19, 2017, which prohibited the planting and cultivation of soybeans succeeding soybeans in the same area and agricultural year, the popular soybean safrinha. It also instituted the planting calendar for soybean cultivation, which is allowed from September 16 to December31. It should be noted that soybeans cannot be sowing before September 16, even if seedling emergence only happens after the start date of the sowing calendar.

The government of Mato Grosso do Sul, through SEMAGRO, published RESOLUTION SEMAGRO no. 648, of August 15, 2017, which ratified the existing state legislation, in addition to meeting the determinations of the new PNCFS[29].

At the federal level, the Ministry of Agriculture, Livestock and Supply (MAPA) was initially established, initially the National Program for the Control of Asian Soybean Rust (PNCFS) by Normative Instruction No. 2 of January 29, 2007 [30], which is currently repealed and replaced by the new PNCFS of Ordinance No. 306 of May 13, 2021 [31] . In it, mapa establishes phytosanitary measures for pest control and competencies to the State Organs of Plant Sanitary Defense.

The current PNCFS, established that the period of sanitary void must have a minimum duration of 90 days, with annual occurrence, be published annually by MAPA, with the decision taken together with the State Organs of Plant Sanitary Defense, and that the dates of coverage of each Unit of the Federation, can be established in a regionalized manner, with different dates, within the same Federation Unit. It also implemented the sowing calendar, which was defined as the single period of up to 110 consecutive days, for the start and end dates of soybean sowing. The new PNCFS also made mandatory the registration of soybean planting areas and delegates the competence of receiving it to the State Organs of Plant Sanitary Defense [1].

The entire legal framework in force can be translated, to Mato Grosso do Sul, in some phytosanitary measures that must be taken together by all producers, concomitantly.

Any disagreement with legal phytosanitary measures will cause the offender to receive administrative sanctions,

such as fines, destruction or elimination of irregularly cultivated crops and voluntary plants or socio-educational measures.

g) Asian rust control strategies in soybeans

Asian soybean rust is a disease that requires planning and use of different management strategies, including before planting and, to achieve control results, as efficient as possible, it is mandatory to integrate preventive cultural measures. As a strategy in the management of the disease, Embrapa recommends the absence of soybean sowing and the elimination of voluntary plants in the off-season through the sanitary void to reduce the fungus inoculum.

Another technique adopted as a disease escape strategy is the use of early cycle cultivars and soweds at the beginning of the recommended season, according to agroclimatic zoning and also the use of fungicides in a preventive manner. These measures aim at preventing the disease from leakage in relation to the presence of the pathogen and/or the environmental conditions more favorable to its development Embrapa (2017) or Godoy et al., 2017[1][22].

The occurrence of Soybean Rust is closely related to weather conditions. Thus, meteorological information obtained with the monitoring of temperature and relative humidity, and other climatological variables (rainfall, dew point and leaf wetting) are used as a subsidy in the prevention and control of the disease. According to Sentelhas (2004), the duration of the leaf wetting period (PMD) is one of the most important factors that influence the propagation and severity of plant diseases caused by fungi and bacteria, because the presence of water in liquid form on the surface of plants allows the germination and penetration of phytopathogenic agents in leaf tissues. In this sense, the predictions about the time for the near future are important for decision-making about the treatment with fungicides in relation to the installation and/or evolution of soybean rust.

It also influences the development of the disease the microclimate that forms inside the crop canopy, because it is related to the spacing between the planting lines, which influences the ventilation between them and the dispersion of moisture. Maldalosso et al., 2010, apud Lemes & Gavassoni (2015), observed that greater spacing between the lines (60cm) provided lower values of accumulated disease and higher productivity[32].

Regarding the biological control of the fungus Phakopsora pachyrhizi, Goellner et al. (2010), apud Lemes & Gavassoni (2015) report that there are few alternatives studied: two species of hyperparasite fungi Lecanicillium psalliotae and Simplicillium lanosoniveum, which develop in leaves already infected by P. pachyrhizi, reducing the pustules of this. However, despite the promising results, there are some limitations, such as leaf wetting necessary for the development of hyperparasite species, which hinder and limit their use, even if associated with other control methods[32].

Rust management is mainly done by the use of chemical control, however, the high number of applications evidenced in recent years, results in loss of fungicide efficiency and development of resistance, since the characteristic of being polycyclic, favors adaptation to active ingredients, due to a series of mutations that accumulate in the genome of the fungus, as reported by Schmitz et al. (2014); Klosowski et al. (2016); Simões et al. (2018) apud EMBRAPA, 2020[1]. Converging with these conclusions, Reis et al, (2018) observed that the use of fungicides impacts on the cost of production andincreases the risk of selection of resistant fungal lines and both factors are dependent on the number of sprays and that no scientific criteria is adopted to define when to make the first application[33]. This process is cyclical, especially if strategies to combat resistance are not adopted [32] as the use of fungicides with different mechanism of action.

There are three main groups of active ingredients recommended for chemical control of Asian soybean rust and recorded in mapa: Demethylation Inhibitors (MDI) – "triazois"; External Quinone inhibitors (IQe) – "strobilurines" and Succinate Dehydrogenase Inhibitors (ISDH) – "carboxamides". In addition to these, there are multisite or protective fungicides (mancozeb, chlorothalonil, copper-based fungicides) which are the combination of more than one active ingredient in the formulation [21].

In general, among the control alternatives for diseases, genetic resistance is a solution that requires a long period of development, but which becomes an excellent form of disease management. In the case of soybean rust, the plant reaction will interfere with the degree of the injury caused by the pathogen and the viability of its reproduction in the plant.

The fig. 6 demonstrates the differences between the degrees of resistance to soybean rust. Resistant plants do not present lesions (A); plants with partial resistance present RB-type lesions, where the pathogen develops the lesion, with reduced urenian production and size (B); susceptible plants present TAN-type lesions, which show full reproduction of the pathogen and are indicative of susceptibility (C).

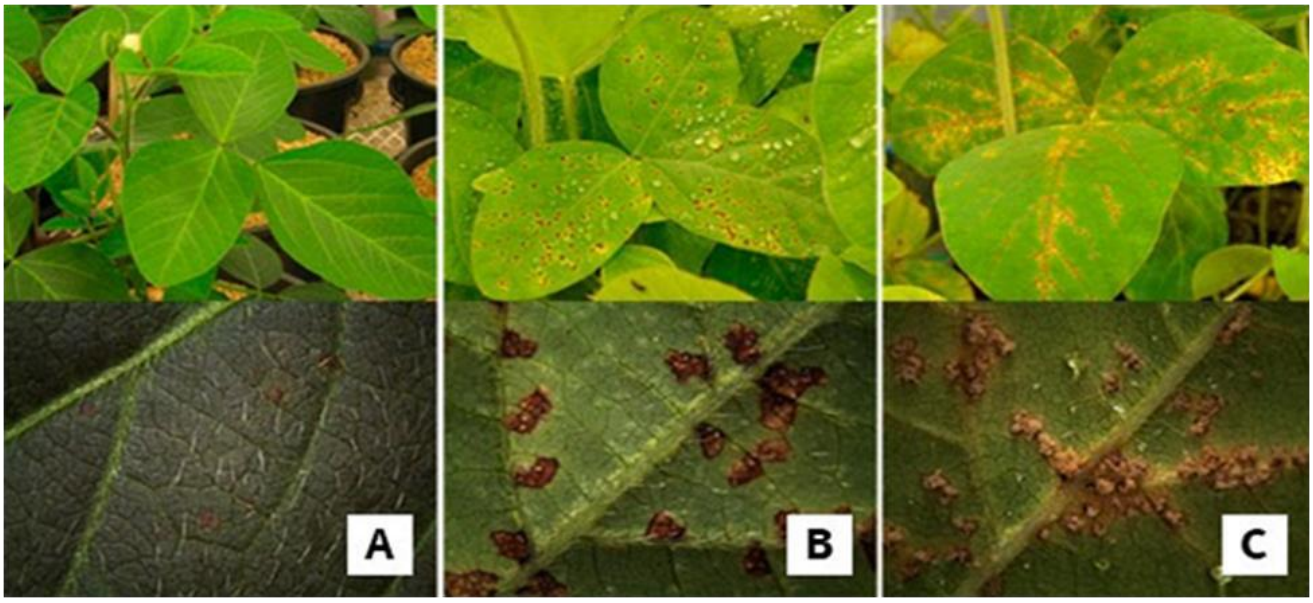

Fig. 6: The three types of qualitative response of soybean to P.pachyrhizi infection: immunity or complete resistance (A), RB lesions or incomplete resistance (B) and TAN lesions indicative of susceptibility (C). Source: Pionner, 2016

With regard to specific resistance to P. pachyrhizi, seven dominant genes were identified: Rpp1 [34], Rpp2 [35], Rpp3 [37], Rpp4 [38], Rpp5 [29], Rpp6 [37] and Rpp7 [40]. However, these genes confer resistance to some biotypes, but are not effective against all populations of the pathogen.

Cultural Control - Soy Sanitary Void in Mato Grosso do Sul

The most important and ancient phytosanitary measure taken and being almost unanimous among researchers, public sector and producers is the sanitary void of soybeans, which was established by legislation as a defined and continuous period in which one cannot sothe or maintain live plants of a plant species in a given area, with the aim of reducing the inoculum of diseases or population of a given pest, as stated in Ordinance No. 306 of May 13, 2021 [41].

One of the paradigms of phytopathology is the disease triangle, in which the conditions for a disease to settle are formed: susceptible host, virulent pathogen and favorable environment. And by eliminating one of these components, the disease cannot settle. The logic of the sanitary void is to make the establishment of the disease unfeasible due to the lack of host, since the interaction of pathogen, host and environment factors is essential for the occurrence of diseases in plants [42].

This is the biological basis for the adoption of the sanitary void of soybeans, which is a mandatory and very effective management measure, which prohibits soybean planting for a period of 60 to 90 days and requires the eradication of guaxs soybean plants, or spontaneous growth, whether in the crop, on the roadside, preventing or minimizing "green bridges". However, in the case of this sanitary measure, it must be respected collectively. If a farmer does not respect the sanitary void of soybeans, it can endanger the health of neighboring crops. Another important consequence of the sanitary void of soybean is the reduction of the possibility of selection of p. pachyrhizi populations resistant to fungicides available in the market.

The occurrence of Asian rust in the 2005/2006 crop, which had a great economic impact on the soybean production chain, promoted or stimulated efforts for the participants of the chain to promote discussions to mitigate the impacts of the fungus on crops, which worsened each crop.

Thus, the implementation of measures to prevent and control Asian soybean rust in the State of Mato Grosso do Sul began to be discussed on May 4, 2006, when a rural union meeting of Chapadão do Sul was held with the presence of about 70 participants among producers, technicians and researchers, together with representatives of IAGRO. Similar meeting took place in the municipality of Maracaju. It was the beginnings of state legislation that is the basis for prevention, control and eradication of Asian Soybean Rust in Mato Grosso do Sul, which has been described earlier, whose initial landmark was State Law No. 3.333.333.

At the time the law came into force, to clarify producers about the new legal requirements, the Health Education Division, together with the Division of Plant Sanitary Defense and in partnership with rural unions and inPEV - National Institute of Empty Packaging Processing, held a series of lectures for producers, in the main soybean producing regions of the state, to present the new law and the technical foundations that guided the new conducts, the care with the management of the crop that became mandatory and also how the inspections would be carried out and what sanctions would be imputed to producers in case of commit of infractions.

Other states, before the MS, had already adopted the sanitary void of soybeans and others adopted it later, including the neighboring country Paraguay, in 2011, as shown in fig. Six, six.

PA (1): Microregions of Conceição do Araguaia, Redenção, Marabá, São Félix do Xingu, Parauapebas, Itaituba (except for the municipalities of Rurópolis and Trairão) and Altamira (District of Castelo dos Sonhos and Cachoeira da Serra). PA (2): Microregions of Paragominas, Bragantina, Guamá, Tomé-Açu. Salty. Tucuruí, Castanhal. Arari, Belém, Cametá, Boreholes of Breves and Portel. PA (3): Microregions of Santarém, Almeirim, Óbidos, Itaituba (municipalities of Rurópolis and Trairão) and Altamira (except the districts of Castelo de Sonhos and Cachoeira da Serra).

MA (1): Microregions of Alto Mearim and Grajaú: Chapadas do Alto Itapecuru, Chapadas das Mangabeiras; Generals of Balsas, Empress; Porto Franco. MA(2); Microregions of Urban Agglomeration of São Luís; Baixada Maranhense; Lower Parnaíba Maranhense; Boxes; Chapadinha; Codó, Coelho Neto; Gurupi; Itapecuru Mirim; Maranhenses Sheets; Maranhense West Coast; Middle Mearim; Pindaré; President Dutra; Rosary.

Paraguay (1): Eastern Region from 06/01 to 08/30 (Res. nº 071/11). Paraguay (2): Occidental Region from 15/06 to 15/09 (Res. N. 633/17)

Fig. 6: Periods of sanitary vacuum in Brazilian states and Paraguay, established by regulations in their respective phytosanitary defense agencies. Source: Embrapa, 2020

During the period of the soybean sanitary void (June 15 to September 15) IAGRO inspectors make visits to rural properties in order to inspect the cultivation area and other adjacent areas regarding the destruction of soybean crop residues (raccoon, rebolded or planting).

This worksees you as objective to characterize the health defense actions carried out by IAGRO regarding the supervision and application of legislation that deals with the sanitary void of soybeans aiming at maintaining the control of Asian rust in the State of Mato Grosso do Sul.

II. MATERIAL AND METHODS

a) Research Design

In this work, a survey of the supervisory actions of the state agricultural inspectors agronomists of IAGRO related to the conduct of activities to control Asian soybean rust in

the State of Mato Grosso do Sul was carried out. Data were searched for the period from 2006 to 2021, both in the former Phoenix system and in the current one, e-Saniagro.

Data were used regarding fines for lack of registration, for non-control of plants and due to planting during the period of the sanitary void. It was also determined the number of participants and the number of Socio-educational Seminars held for lack of registration of soybean plantation, soybean planting areas registered, areas inspected in the harvests and amount of infringement notices drawn up each period of inspection of the sanitary void are stored in the computerized systems of IAGRO.

b) Data collection at IAGRO

The State Agricultural Inspectors (FEA) - agronomists carry out annually, during the sanitary void of soybeans, on-site inspections in soybean producing properties in order to ensure compliance with the legislation for the control of the disease.

Inspections are based on planning according to the data obtained from the registration of soybean plantations (required by law) for the current crop. From the listing of registered properties, the FEA responsible, after thorough analysis, plans with the IAGRO coordination the field inspection actions. In the inspections, it is verified whether the producer has fulfilled the soybean void period, with the destruction of irregular plantings, or of plants that were born spontaneously from grains lost during harvest or transport.

The quantitative execution of inspections is based on the resources made available through a federal agreement with MAPA and resources of the Government of the State of Mato Grosso do Sul. The amount of resources available is adjusted together with the IAGRO board server team.

In case of non-compliance with current legislation, penalties are applied according to the violation observed. Cash penalties are fixed in the State Reference Tax Unit of Mato Grosso do Sul - UFERMS, whose value is indexed in national currency (Reais) and is often adjusted. Table 1 presents the value in UFERMS corresponding to the main infractions to the legislation of the sanitary void of soybeans.

Table 1: Violations of the Law of The Sanitary Void of Soy and amount of the fine. Source: e-Saniagro, IAGRO/MS

Violations of the Soy Sanitary Void Law and corresponding penalties	
Infraction	**Basic amount of fine in UFERMS**
□ Lack of registration of the planting area	□ 100 UFERMS
□ Non-disposal of raccoon plants	□ 200 UFERMS
□ Non-compliance with the sowing schedule, with graduation according to size of irregular area	□ 200 UFERMS
□ Not performing any type of disease control	□ 400 UFERMS
□ Soybean planting in succession to soybean (safrinha) with graduation according to irregular area size	□ 1000 UFERMS
□ Planting during the period of the sanitary void	□ 1000 UFERMS
Value of UFERMS in November 2021: R$42.56	

The inspection reports feed IAGRO's data storage systems, along with the mandatory registrations made by the producers, informing the planting areas that they will carry out in the current harvest. With the evolution of the system, the data stored between 2009 and March/2017 (Fênix System) were migrated to the official system database, currently in use, the e-Saniagro.

III. RESULTS AND DISCUSSION

After the implementation of the period of sanitary void and the mandatory registration of planting of soybean areas in the MS, these have been periodically supervised to verify compliance with the legislation. To optimize the actions, several technological tools are used for data analysis, being possible to achieve an optimization of the staff of the servers and a better assertiveness, prediction and resolution of irregularly identified events. The dynamicity, an intrinsic characteristic of agriculture, reinforces the need for constant evolution of legal instruments. The implementation of new legislation causes much resistance and questioning on the part of producers and members of the chain who are affected by the measures.

In order for any implementations or changes in legislation to be disseminated and clarified, with a view to compliance by those involved in the production chain, IAGRO relies on the Health Education Division, which is responsible for preparing and conducting interactive lectures that are held in the field, to clarify producers, develop educational support material, such as folders and flyers, in addition to preparing and disseminating legal deadlines in various communication channels.

To specifically meet the legislation of the Soy Sanitary Void, the Division of Sanitary Education holds socio-educational seminars, composed of two lectures, for the lack of registration of soybean planting areas since the year 2010, and since December 2020, the seminar has been held in the modality of videoconference, due to the pandemic of Covid 19. The fine for failure to register, which is classified as a minor infraction, is 100 UFERMS and can be converted entirely into a socio-educational measure, as stated in Law 3.606/2008. The lectures address the cycle of the fungus of Asian rust, the biological principles for the adoption of the sanitary void, all relevant legislation and the importance of sanitary defense for the country. In all, 664 employees have benefited from registering soybean areas. Table 2 presents the data by municipality where the socio-educational seminars were held.

Table 2. Socio-educational seminars held for employees due to lack of registration.

Des/DDSV Socio-Educational Seminar				
Plant Sanitary Defense and Soybean Sanitary Void Law				
#1	**Municipality**	**Date**	**Number of Participants**	**Total**
First	Campo Grande	17.12.2010	39	39
2nd	Campo Grande	12.06.2011	63	63
Third	Campo Grande	1st.12.2011	7	40
	Golden	02.12.2011	33	
4th	Campo Grande	26.04.2012	22	86
	Golden		36	
	New Andradina		17	
	Ponta Porã		11	
5th	Campo Grande	06.12.2012	12	56
	Costa Rica		6	
	Cushion		1	
	Golden		19	
	New Andradina		3	
	Ponta Porã		15	
6th	Campo Grande	28.11.2014	16	41
	Costa Rica		3	
	Golden		18	
	New Andradina		4	
7th	Campo Grande	18.03.2016	22	26
	New Andradina		4	
8th	Campo Grande	18.11.2016	38	74
	Costa Rica		5	

	Golden		20	
	Naviri		3	
	New Andradina		8	
9th	Campo Grande	08.06.2017	9	33
	Cushion		3	
	Golden		10	
	Naviri		1	
	New Andradina		10	
10th	Campo Grande	07.12.2017	7	19
	Costa Rica		1	
	Golden		4	
	Naviri		3	
	New Andradina		4	
11th	Campo Grande	08.06.2018	9	28
	Costa Rica		4	
	Golden		6	
	Naviri		1	
	New Andradina		7	
	Ponta Porã		1	
12th	Campo Grande	06.12.2018	26	60
	Golden		19	
	N. Andradina		15	
13th	Campo Grande	14.06.2019	6	23
	Golden		1	
	N. Andradina		16	
14th	Campo Grande	05.12.2020	7	18
	Golden		4	
	N. Andradina		7	
15th	Campo Grande - On Line	03.12.2020	14	14
16th	Campo Grande - On Line	19.03.2021	15	15
17th	Campo Grande - On Line	25.08.2021	12	12
18th	Campo Grande - On Line	01.09.2021	17	17
TOTAL				**664**

In thefig. 7 data from estimated planting areas (IBGE), areas registered in IAGRO and inspected areas in the 2006/07 harvests to 2014/15 are demonstrated.

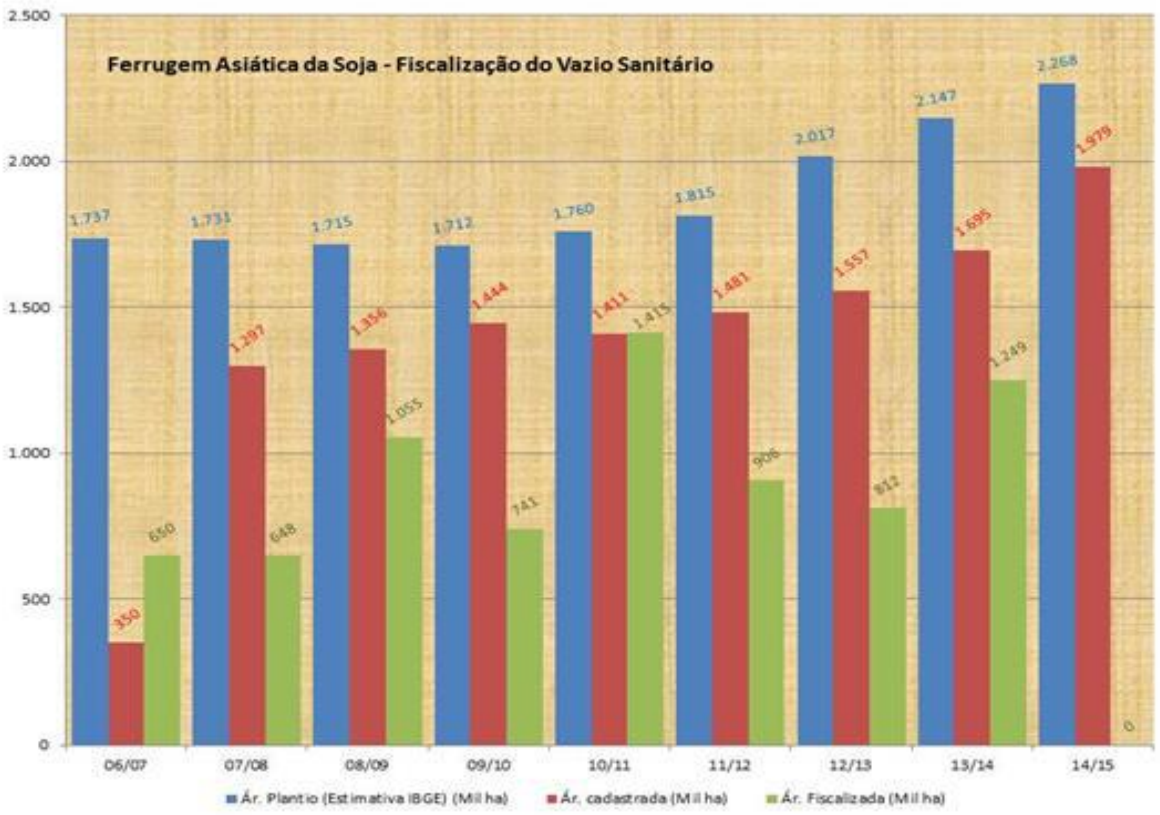

Fig. 7: Estimated planting areas (IBGE), areas registered in IAGRO and areas inspected in the 2006/07 harvests to 2014/15.

Through a survey in the IAGRO database, from 2009 on, it was observed that, after the entry into force of the Soybean Sanitary Void Law and the inspection activities of the planting areas, soybean crops during the lifetime of the sanitary void were few. In addition to having been widely disseminated the legislation in the media, at the time of its entry into force, lectures were also held to clarify the new legal requirements and on the biological foundations for the empty sanitary adoption. Thefig. 8 shows the number of assessments that occurred during the 2009/10 harvests until 2020/21. The largest amount was due to the lack of registration of soybean planting areas, and in the 2020/21 crop there was an increase of 177% in the cases. This may be related to the fact that there was an increase in the planted area of soybean, with even in regions that had livestock as the main activity [1], in this case, producers beginning in the activity, may not have knowledge about the legal requirement to register the areas. It is observed that there were few assessments for non-compliance with the sanitary void, and there was an increase in the 2014/15 crop and then 5 cases in the 2019/20 crop, There was also an increase in the occurrence of fines for not controlling raccoon plants in the 2017/18 crop, followed by two harvests with this fall parameter and a new increase in the 2019/20 20 2020/21 harvests. As for fines for lack of chemical, biological or mechanical control of soybean rust already installed, in this period analyzed, there were only 4 assessments.

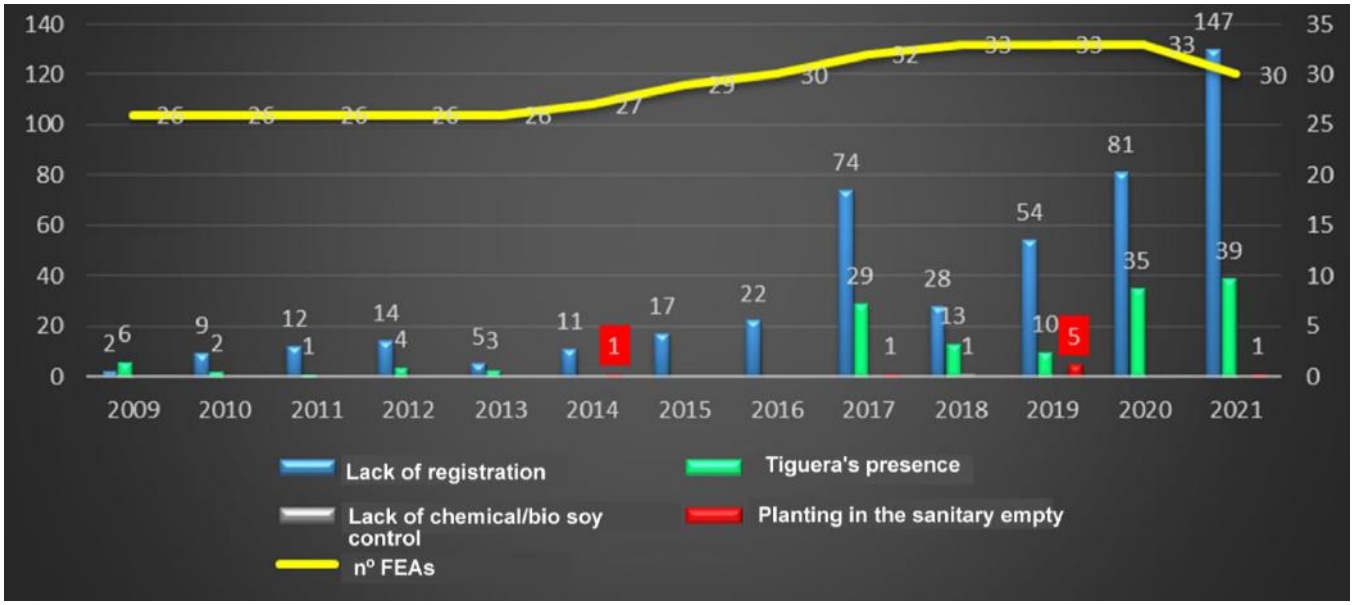

Fig. 8: Infraction notices in the 2009/07 to 2020/21 harvests. Source: e-Saniagro/IAGRO.

In relation to the inspectors who act to curb the non-compliance with the sanitary legislation, from the year 2020, there was a reduction in the number of staff, which may cause some difficulty to meet the inspection targets, if the trend of increase in soybean areas in the state of Mato Grosso do Sul persists.

IV. CONCLUSION

In the state's production matrix, soybean cultivation has become a master activity of the South Mato Grosso economy due to its connection with the industrial sector and partly with the service sector. Thus, negative variations in productivity may affect the state's production chain and economy.

Given IAGRO's history of action in the last 20 years, in the face of Asian soybean rust, it is known that its control permeates the work carried out by IAGRO in promulgating competent legislation.

An essential factor for compliance with the legislation is in the work carried out by the Agronomists and Technicians FEAs. Therefore, the decrease in servers due to retirements, medical leave and other factors will increase the risk for maintaining the control status achieved, and consequently, the improvement of IAGRO's actions.

Although we have specific laws at the national and state level to control soybean rust, such as the soybean planting schedule and also the strict control of inspections carried out by IAGRO, it was necessary to implement the prohibition of the planting of soybeans in second harvest, in succession to soybean, in the same area and in the same agricultural year. Even with all preventive measures and with farmers having already become aware that this period of sanitary vacuum must be respected, all care is not sufficient, because this pathology has as characteristic the propagation through the action of air currents and even if excellent management is carried out in the off-season, it will still occur, with greater or lesser intensity, depending on weather conditions.

All this is reason to further promote the actions of awareness of producers, through educational actions and thus giving support to the strict control made by inspection actions, after all, the aim is to maintain the sanity of our crops, the safety of the food we produce and safeguard the market, since soybeans is a product with great importance for the economy of the state and Brazil.

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