

RESEARCH ARTICLE

# Two decades of national registry of soybean cultivars: updates and perspectives

Jardel Bazzan Dorneles<sup>1</sup>, Ivan Ricardo Carvalho<sup>1\*</sup>, Tamires da Silva Martins<sup>2</sup>, Natã Balssan Moura<sup>1</sup>, José Antonio Gonzalez da Silva<sup>1</sup> and Francine Lautenchleger<sup>3</sup>

<sup>1</sup>Universidade Regional do Noroeste do Estado do Rio Grande do Sul, Ijuí, RS, Brasil

<sup>2</sup>Universidade Federal de Pelotas, Capão do Leão, RS, Brasil

<sup>3</sup>Universidade do Centro-Oeste, Guarapuava, PR, Brasil

\*Author for correspondence: carvalho.irc@gmail.com

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## ABSTRACT

The aim was to reveal the trend and the pattern of registration of soybean cultivars in Brazil in recent decades and to contrast with future perspectives. This is a study carried out in 2019 at the Regional University of Northwestern Rio Grande do Sul - UNIJUÍ, where data were collected from 1998 to 2018. The online databases of the Ministry of Agriculture, Livestock and Food Supply (MAPA) were used, Food and Agriculture Organization (FAOSTAT) and United States Department of Agriculture (USDA), for data collection, the criterion used was that the cultivar was properly registered on the National Register of Cultivars (NRC) platform. In general, the aspects according to each year of launch of the cultivars are in favor of the best performance of the crop. They are correlated in the following modifications: plant architecture, resistance, seed size, indeterminate growth habit, flower colors, pods, hilums, presence of anthocyanin, peroxidase, seed brightness, densities and registered genotypes. With neural networks it was possible to classify 1818 soybean genotypes, divided into 18 profiles, also based on the search for 68 characters presenting 19 trends. With the work it was concluded that the year of launch of the cultivar is associated with: the intrinsic characteristics of the maintainer of the cultivar, the biotechnological event, the characteristics of the growth habit and the colorations of the flower, of the seed pod and of the hypocotyl. As the forecast is that in the coming decades new cultivars will be launched in Brazil, a correct positioning of specific genotypes for different environments is needed.

## Highlighted Conclusions

1. The profile of traits of soybean cultivars has changed over the decades.
2. Brazilian soybean cultivars can be classified into 18 characteristic profiles.
3. The new cultivars are dependent on changes in the internal and external market.

## INTRODUCTION

Brazil is the world's largest producer of soybeans (*Glycine max* L.), producing approximately 117 million tons of grain (Costa 2018), therefore responsible for 33% of all world production of this crop, surpassing the United States of America, which contributes 32% of the production amount (USDA 2019). It is one of the most important Brazilian commodities, with constant growth. In the 2018/2019 harvest, production was 114 million tons of grain, a planted area of 35 million hectares and yield of 3,206 kg ha<sup>-1</sup> (CONAB 2019).

As the largest crop in a sown area in Brazil, totaling more than 34 million hectares of production, the soybean production chain contributes significantly to the generation of formal jobs and income, demonstrating the economic importance that the soybean crop has in the country. In addition to covering a large number of agents and organizations that are connected to the most varied economic sectors, it contributes significantly with respect to the country's gross domestic product (GDP), as well as to the generation of foreign exchange (Lazzarotto and Hirakuri 2010).

Soybean is gaining more and more importance in world agriculture. Due to the great diversity of the use of oilseeds and the increase in the global demand for food, the area destined to the soybean growing has been increasing annually (Moreira 2012). Production, encouraged by international demand and attractive prices, was

responsible for accelerating the mechanization of crops, modernizing the transport system, expanding the agricultural frontier, professionalizing and increasing international trade, modifying and enriching the diet of most Brazilians and, consequently, for accelerating rural exodus and urbanization in different regions of the country. It also served as a basis for boosting and decentralizing agro-industries, enabling and expanding wheat cooperatives and promoting expansion and modernization in other agricultural activities, such as corn, pigs, poultry and milk (Trennepohl and Paiva 2011).

The choice of cultivar must be made taking into account three requirements: the growing region, the crop cycle, and the quality of the grain. Not choosing correctly the material to be grown has a negative impact on yield and quality, since each variety has different characteristics that imply mainly the adaptation to the environment, which may cause signs of non-uniformity in the crop (Embrapa 2005, Rezende and Carvalho 2007). The seed, to be considered of high quality, must have excellent physiological and health characteristics, such as high levels of vigor, germination and health, as well as guarantee of physical and genetic purity (França Neto et al. 2010).

The final yield of this oilseed is determined by biotic and abiotic factors intrinsic to the environment in which it grows, considering that high-performance seeds are characterized as the main agricultural inputs (Szareski et al. 2018, Carvalho et al. 2017). The peak of the expansionist soybean cycle was marked in the 1970s, due to the excellent quotations of the product in the international market and its placing on the market during periods of American off-season, providing, year by year, a substantial increase in supply, to the point that it became the main crop of Rio Grande do Sul (Tedesco 1993). There are many factors that contributed to the establishment of soybean as an important Brazilian crop. Among some reasons that cooperated for its rapid establishment in the Southern Region, we can highlight the similarity of the ecosystem of Southern Brazil with that prevailing in the Southern United States, favoring the success in the transfer and adoption of varieties and other production technologies, and also the replacement of animal fats by vegetable oils, healthier for human consumption. The increasingly frequent use of technology and the degree of professionalization of the activity, directly produces results in the country's agricultural potential.

The soybean breeding programs aim predominantly at the selection of genotypes with characteristics that allow higher yields. For that, more productive lines are selected, resistant to pests, diseases, adapted to different conditions of climate, soil, photoperiod and that allow the incorporation of new areas, allowing greater profitability for the grower (Krzyzanowski 1998, Bueno et al. 2006, Vasconcelos et al. 2012). The use of seeds with high genetic, physical and physiological quality is essential to obtain satisfactory results in economically expressive crops (Carvalho and Nakagawa 2012).

There were two major contributions of genetic improvement to soybean crop in Brazil: the first was the adaptation of soybean to low latitudes, through the introduction of genes for the "long youthful period" of Brazilian germplasm - starting point so that the crop could spread in the savanna; the second was the increase in resistance to the most significant diseases in the crop, such as the bacterial pustule, the frog-eye leaf spot, the stem canker, the cyst nematode, the root-knot nematode and the common mosaic. An essential factor that allowed for rapid genetic progress in improving soybeans was the existence of an experimentation network, shared by the various public and private soybean breeding programs (Embrapa, Ocepar / Coodetec, FT, Indusem, Cotia etc.). Through this network of tests, the lines were evaluated together (intermediate and final tests) and all participants had access not only to the results of the tests, but also to the germplasm, for the purposes of crosses. That is, once a superior line has been identified, it can be quickly recombined with other elite lines in each of the programs, between 4 and 5 years before reaching the farmer's hands, in the form of a new variety (Calvo and Kiihl 2006). In order to obtain superior genotypes, it is necessary to gather a series of favorable attributes that provide higher grain yields and satisfy market requirements (Cruz and Regazzi 1997).

The yield increases in the South Region are unquestionable results of the benefit achieved through the creation of new cultivars adapted to these growing conditions. The expansion of the number of cultivars available for the various soybean growing regions in Brazil is still a priority for improvement with the aim of providing the farmer with the planting options that best meet their needs. In the traditional planting areas, a large part of the soybean breeding effort is concentrated, it is in these areas that the creation of new cultivars reaches levels of high complexity, due to the presence of well-adapted cultivars and the multiplicity of objectives to be achieved to replace them (Toledo et al. 1990).

Research on genetics and soybean breeding in Brazil is quite recent compared to other crops of economic importance, but its contribution to Brazilian agriculture is quite significant. Crop breeding programs are essential to meet the growing demand for greater yields, allowing for increased variability and consequent expansion of the genetic base and the selection of the best genotypes of a population capable of exceeding the levels of grain yield

(Toledo et al. 1990, Costa et al. 2004). This work aims to reveal the trend and the pattern of registration of soybean cultivars in Brazil in recent decades and to contrast with future perspectives.

## MATERIAL AND METHODS

This is a study carried out in 2019 at the Regional University of Northwestern Rio Grande do Sul - UNIJUÍ, where data were collected from 1998 to 2018. The online databases of the Ministry of Agriculture, Livestock and Food Supply (MAPA) were used, Food and Agriculture Organization (FAOSTAT) and United States Department of Agriculture (USDA), for data collection, the criterion used was that the cultivar was properly registered on the National Register of Cultivars (NRC) platform. Table 1 describes the 68 genotypes measured in the period established according to the database used.

The data obtained are classified into two categories of random variables, of which the continuous and discrete distribution are evident. For the discrete random variables, the information was frequented so that each discrete random variable was then understood through the frequency of events and made it possible to obtain parameters (mean and variance). After the construction of the quantitative matrix, for the 68 characters measured, linear regression based on the model ( $y$ ) dependent character = (a) intercept + angular coefficient (year of launch) ( $R^2$  coefficient of determination of the statistical model) was performed, with significance based on the t test at 5% probability, all characters were submitted to Spearman's linear correlation at 5% probability by the t test to then understand the degree of association of the attributes of interest.

Subsequently, a predictor model was created to understand which attribute of the soybean production chain determines the launch of new genotypes, in this context, it was fixed as a dependent character ( $y$ : the number of genotypes launched per year) and a multiple regression model was applied to select Stepwise variables. In order to identify patterns for the release of cultivars in Brazil and to determine which measured variables are associated with each established pattern, the Artificial Neural Networks (ANNs) approach was used, basing their estimates through unsupervised computational learning. The topological definition of the centroids and associated neurons was obtained by the Kohonen Mapping method, using 1,000,000 iterations, and three artificial neural networks were made, the first being the definition of patterns fixing the years of genotype launch, the second based on the definition of variable profiles and the third identifying which cultivars launched have a similar pattern.

Statistical analyzes were performed using Softwares SAS® (Statistical Analysis System®).

## RESULTS AND DISCUSSION

**Current Linear Trends and Perspectives.** Since 1998, over 1,818 soybean genotypes for growing in the most varied Brazilian edaphoclimatic conditions have been registered with the Ministry of Agriculture, Livestock and Food Supply (MAPA). This registration increase occurred due to the increases in sown area, yield, production and exports of these grains, as well as the use of these legumes for human and animal feeding, and industry.

It is noted that in 2018 more than 250 new genotypes were registered and it is revealed that the characteristics prioritized by breeding have undergone certain changes, such as the tendency to reduce the magnitude of cultivars without the presence of biotechnological events and to enhance those that reveal technologies aimed at herbicide resistance, tolerance to insect pests and diseases. Aspects such as the morphological attributes expressed modifications and establish that the habit of indeterminate growth is currently preferable for the soybean market, this inversion of trends was occasionally established in 2011.

Over the past few years, Brazilian soybean production has shown a great advance, driven not only by the increase in the area, but also by the application of advanced management techniques that allowed the increase in yield. As a result, soybean has consolidated its position as the largest crop explored in Brazil, and has shown significant economic importance and has led to progress and development in the various growing regions. Exports are relevant for macroeconomic adaptation, for development policies and for maintaining our agriculture strengthened (Freitas 2011).

Grain production in millions of tons fluctuated (1998 to 2018) between 38 and 120 million tons of grains. Estimates indicate an increasing behavior of this character ( $\hat{Y} = -7893512 + 0.047x$   $R^2 = 0.61$ ) as the agricultural years advance, future trends represent an increase of 0.5% in grain production in the next 10 years (2020 to 2030) and a scenario with 1.6% for the next three decades (2020 to 2050). Grain exports between 1998 and 2018 varied between 10 and 50 million tons, according to the behavior of this character  $\hat{Y} = -3790.697 + 1.901x$   $R^2 = 0.97$ . The importance of these values has been determined over the years by the world market, in which the trend for the next 10 years (2020 to 2030) is an increase of 38.5% in grain exports and for the next three decades (2020 to 2030) a 46% increase of grain exports.

**Table 1. Description of the 68 characters measured during the years 1998 to 2018 based on the Food and Agriculture Organization (FAOSTAT), Ministry of Agriculture, Livestock and Food Supply (MAPA) and National Register of Cultivars (NRC).**

Character	Initials	Character	Initials
Area sown with soybean * *	AREA	Seed with brown hilum ** 1	HBRO
Grain yield per hectare * **	YIELD	Seed with light brown hilum ** 1	HLB
Grain production * ***	PROD	Seed with dark brown hilum ** 1	HDB
Grain exports * ***	EXPM	Seed with medium brown hilum ** 1	HMB
Grain imports * ***	IMPM	Seed with imperfect black hilum ** 1	HIB
Grains intended for human consumption * ***	HFOOD	Presence of anthocyanin in the hypocotyl ** 1	PRES
Grains for animal feed * ***	AFEED	Absence of anthocyanin in the hypocotyl ** 1	ABSA
Production of soybean seeds * ***	SEED	Negative peroxidase activity ** 1	PERN
Cultivars launched per year ** -	NCLA	Positive peroxidase activity ** 1	PERP
Annual cultivar launch rate ** -	ACLR	Intermediate peroxidase activity ** 1	PERI
Conventional genotypes ** 1	TCON	Seed with elongated shape ** 1	SELO
Genotypes with Cultivance® technology** 1	TCUV	Seed with elongated/flat shape ** 1	SEF
Genotypes with IPRO® technology** 1	TINT	Seed with rounded shape ** 1	SROU
Genotypes with Liberty Link® technology** 1	TELL	Seed with spherical shape ** 1	SSPH
Genotypes with Roundup Ready® technology** 1	TERR	Seed with flat spherical shape ** 1	SFS
Determinate growth habit ** 1	DGH	Seed with elongated spherical shape ** 1	SES
Indeterminate growth habit ** 1	IGH	Seed with spherical oval shape ** 1	SSO
Semi-determinate growth habit** 1	SDGH	Seed with high brightness ** 1	BH
White flower color ** 1	FWHI	Seed with low brightness ** 1	BL
White / purple flower color ** 1	FWP	Seed with medium brightness** 1	BMED
Purple flower color ** 1	FPUR	Bright seed** 1	BBRI
Seed with yellow tegument ** 1	TYEL	Matte seed ** 1	BMAT
Seed with light brown tegument ** 1	TLB	Pod with high pubescence density ** 1	DPHI
Seed with brown tegument ** 1	TBRO	Pod with low pubescence density ** 1	DPLO
Seed with black tegument ** 1	TBLA	Glabrous pod ** 1	DPGL
Pod with gray pubescence ** 1	PGP	Pod with medium pubescence density ** 1	DPME
Pod with light gray pubescence ** 1	PLGP	Pod with gray color ** 1	CPGR
Pod with brown pubescence ** 1	PBP	Pod with light gray color ** 1	CPLG
Pod with light brown pubescence ** 1	PLBP	Pod with dark gray color ** 1	CPDG
Pod with dark brown pubescence** 1	PDBP	Pod with light color ** 1	CPL
Pod with medium brown pubescence ** 1	PMBP	Pod with brown color ** 1	CPBR
Seed with black hilum ** 1	HBLA	Pod with light brown color ** 1	CPLB
Seed with yellow hilum ** 1	HYEL	Pod with dark brown color ** 1	CPDB
Seed with gray hilum ** 1	HGRA	Pod with médium brown color ** 1	CPMB

\* obtained through the Food and Agriculture Organization (FAOSTAT, 2018). \*\* Ministry of Agriculture, Livestock and Food Supply (MAPA, 2018). + million hectares, \*\* tons of grain, \*\*\* million tons, - units, - - percentage, 1 frequency of events observed.

As for the growth of the soybean production chain, it is due to several factors, among them, the constant increase in the world population and the growth in demand for food. Soybean is essential, as it is one of the basic foods for the human diet and extremely important for some animal production chains (Bellaver 2001). It was analyzed that, the soybean seed production had increases during the period (1998 to 2018) from 0.58 to 1.4 million tons, the estimates indicate an increasing behavior of this character  $\hat{Y} = -77,174 + 0.0389x$   $R^2 = 0.94$ . Over the next 10 years (2020 to 2030) there will be an estimated 28% increase in seed production, and consequently over the next three decades (2020 to 2050) the estimate is a 55% increase. These results are directly linked to the greater proportion that the product represents in the world market.

Soybean has stood out on the national scene over the last decades with 49% of the Brazilian agricultural area (MAPA 2015). This increase is mainly due to factors related to crop management, and the various purposes of use. Grain yield is directly associated with the edaphoclimatic conditions of the environment in which soybean is grown, observing an increase in grain yield (Hirakuri and Lazarotto 2014). The results show that research aimed at breeding, increasing the sown area and management techniques have positively boosted national soybean production (CONAB 2019). The importance of soybean can be established through the area sown in Brazil, which in the last 20 years has fluctuated between 13 and 36 million hectares the estimates determine an increasing behavior  $\hat{Y} = -2169763 + 1092.056x$   $R^2 = 0.93$  and represents an increase of 30% in the area sown for the next 10 years (2020 to 2030) and, therefore, for the next three decades (2020 to 2050) an increase of 77%.

Biotechnology and technological events combined with resistance to herbicides and tolerance to insect pests have been a sustainable tool that allows innovation and the launch of new soybean genotypes (Carvalho et al.

2017). Cultivance® technology had a greater prominence until the 2000s and soon after it lost space to other technologies. From 2004, the IPRO® technology, which is a technology applied in the cultivar that provides quality according to the maturity group, has had a progressive increase until the present day and maintains prominence over the other technologies.

A determining factor in soybean yield is the habit of growing the genotype: it can be determinate, semi-determinate and indeterminate, based on the characteristics of the apical meristem and the inflorescence of the main stem. The determinate growth habit is characterized by the growth of the plant until flowering and after that, the plant grows little in stature and does not branch, the genotype develops flowers and later pods from the apex to the base of the plant simultaneously (Floss 2004). In the habit of indeterminate growth, the plants may not show terminal inflorescences, they show a development and elongation for a longer period of time, and after flowering, they still show a certain height increase, with the leaves located at the apex smaller than the basal ones. As for the genotypes of semi-determinate growth habit, they have attributes of both habits and reveal their characters linked to the maturity cycle and the response to the intermediate photoperiod (Mundstock and Thomas 2005).

As shown in Figure 1, the determinate growth habit caused a 100% regression in the 20 years of research, while the indeterminate growth habit increased its frequency by 100%. In 2011, when the two reached 50%, there was a meeting of the curve (the determinate reducing and the indeterminate increasing their frequency). As for the color characteristics of the soybean flower, it can be white or purple (violet). The purple hue varies according to the genetic makeup of the cultivar, and anthocyanin is the pigment responsible for the presence of this color in the flower petals, in the hypocotyl and, sometimes, in the plumes. During the ripening process, when exposed to intense sunlight, the purple color formed by anthocyanin is present in the walls of the pods, petioles and stems. The degree of synthesis and intensity of anthocyanin vary widely, however, it never forms in white flowering plants (Johnson and Bernard 1963). shows the characteristics of the colors of the flowers, it is observed that the frequency of the white flower genotype increased by 40% during the study period, while the white and purple flower and the purple flower had a reduction of 20% of frequency. According to over the 20 years of research, the presence of anthocyanin in the hypocotyl presented a significant increase and the absence of anthocyanin had regression in all years.

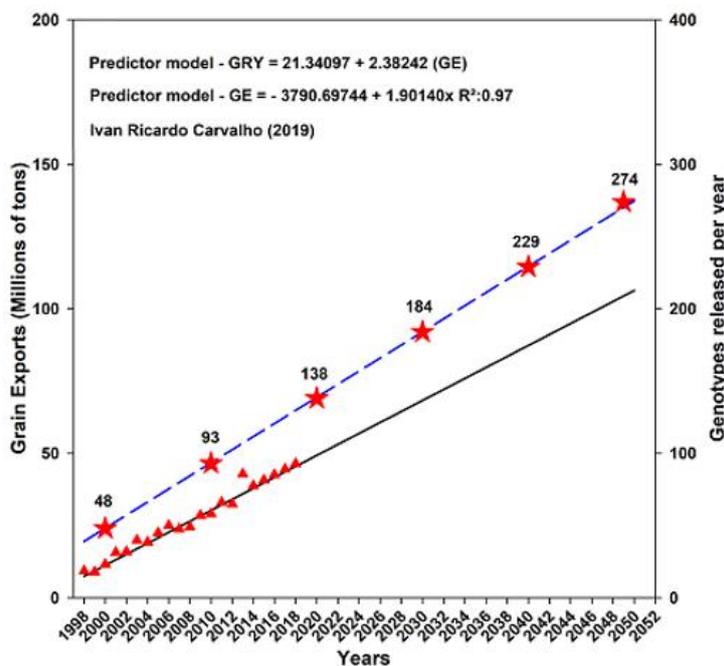


Figure 1. Predictor model based on the multiple regression model.

Another characteristic of soybeans is the tegument colors that are determined by the joint action of several genes. The integument may have one, two or possibly three colors. The characters tegument color and hilum color are very useful to distinguish, in the offspring, the hybrid progeny that results from self-fertilization (Verneti and Verneti Júnior 2009). The seeds with light brown, brown and black tegument over the twenty years of research did not vary. While yellow-tegument seed was 60% higher in frequency, but from 2010 on, it has been regressing.

The colors of the soybean pod vary within the cultivars. It can change from straw yellow, passing through the brown, until the black color. But only three basic colors are considered: straw yellow, brown and black. This character must be used to identify cultivars in seed crops (Verneti and Verneti Júnior 2009). The pubescence pod

with a gray characteristic showed greater prominence throughout the survey, reaching the best performance in 2018. Pods with medium brown pubescence, light gray and dark brown, practically remained stable without major variations. Unlike other pods, the brown pubescence characteristic was losing space and in 2017 it reached 0%, being the worst result compared to other pods.

The hilum is a type of scar through which the seed, before reaching physiological maturation, receives photoassimilated (Sedyama et al. 2013). The colors of the seed hilum are determined by the joint action of several genes. The hilum almost always has a single color. The following colors are found in the hilum: yellow, yellow-imperfect, green, brown (more than one shade), black and black - imperfect and can also be gray (Vernetti and Vernetti Júnior 2009). Sedyama et al. (2013) cites the following colors for the hilum: green, yellow, orange yellow, brown, light brown, brown, dark brown, reddish brown, light grayish, dark grayish, imperfect black, black and saddle type (spill of pigment from the hilum on the integument). The brown hilum was the most representative in the year 1998. However, it presented regression and the dark brown hilum between the years (2002 to 2018) had a progressive increase compared to the others.

The peroxidase activity of soybean seed husks is one of the standard tests used to identify cultivars. This is because genotypes can be divided into two categories: high and low peroxidase activity (Buzzell et al. 1969). The negative peroxidase activity has regressed and positive activity has progressed in the years of research. In 2018 the two lines met at a frequency of 50%. Over the years of research, the line of intermediate activity has not had expressive results.

The seed is variable in shape, from spherical, spherical-flattened, elongated and elongated-flattened, presenting an average size ranging from approximately 2 to 53 g per 100 seeds (Sedyama et al. 1985). The seeds of larger size or those with higher density are those that normally have well-formed embryos and with greater quantities of reserves, potentially being the most vigorous (Carvalho and Nakagawa 2000). The tendency according to estimates for the following years is that the spherical flat seed continues to increase its frequency, as this type of format has always increased in the years of research. However, the spherical shape has been regressing since 2008. The other forms of seeds did not increase significantly. The characteristics of seed with high brightness, medium brightness, low brightness, bright and matte. The low brightness seed was superior and growing in relation to the others, in 2014 its frequency reached 50%. The high brightness seed regressed by 20% in the years 1998 to 2013 and in 2018 it remains stable. The other bright and matte seeds, without great variations, had declines over the 20 years of research. It represents the density of the soybean pods. The pod with medium characteristic has more evidence according to the years of research, and the other pods with high, medium, glabrous and low characteristics did not have great variations.

The basic color of the ripe pod varies from straw yellow, light gray to almost black. The colors originate from the presence of remains of xanthophylls in plastids and flavonols in vacuoles (Müller 1981). The characteristic of the light gray color of the pod from the year of (2007) was predominant over the others until today and tends to have a greater increase in the soybean market. The light brown color of the pod has regressed over the years.

The demand for soybean genotypes with high grain yield potential has been growing and every year companies innovate in the search for information (Carvalho et al. 2017). Regarding the registered genotypes, the study presented the following percentages compared to the technological classes: Cultivance® (CT) technology 31.4% - 570.85 genotypes, Liberty Link® (LL) technology 0.9% - 16.36 genotypes, Conventional (CV) technology 0.6% - 10.91 genotypes, Roundup Ready® (RR) technology 37.6% of which 683.6 are genotypes and IPRO® (IP) technology 29.5%, with 536.3 genotypes.

**Linear Associations for Attributes of Interest.** In view of the linear correlations based on the descriptors of 1818 cultivars registered from 1998 to 2018 in Brazil, the significance was based on a 5% probability of the T Test (Table 2), it is evident that the year of launch of the cultivar is positively associated with: the intrinsic characteristics of the maintainer of the cultivar, the biotechnological event, the characteristics of the growth habit and the colorations of the flower, of the seed pod and of the hypocotyl. As for the biotechnological event used in the cultivar, it is positively associated with the aspects of the growth habit and with the color of the tegument, thus modifying the proportion of the biotechnological events of the cultivars, the habit of indeterminate growth and yellow tegument coloration are also modified.

The essential aspect to characterize soybean cultivars and the color of the flowers in this context is positively associated with the color of the pod, shape of the seed, color of the tegument, density of the pod's pubescence, color of the hilum, color of the pod's pubescence, seed brightness and peroxidase activity. In contrast, the color of the flower is inversely associated with anthocyanin present in the hypocotyl of the seedling, a fact that white colored flowers result in green colored hypocotyls, in the same way that purple flowers are pleiotropically linked to hypocotyls, presence of anthocyanin due to the same gene determining the characteristics together.



The shape of the seed and the color of the seed tegument (Table 3) are highly associated with the densities of the pod's pubescence, color of the seed hilum, presence of anthocyanin in the plant's hypocotyls, color of the pod's pubescence, seed brightness and peroxidase reaction. Therefore, the color of the pod is inversely related to the color of the hilum whereas when launching a cultivar with a morphological genetic marker it tends to modify a specific descriptor.

**Table 3. Significant linear correlations to the t test at 5% probability for the descriptors of 1,818 soybean genotypes.**

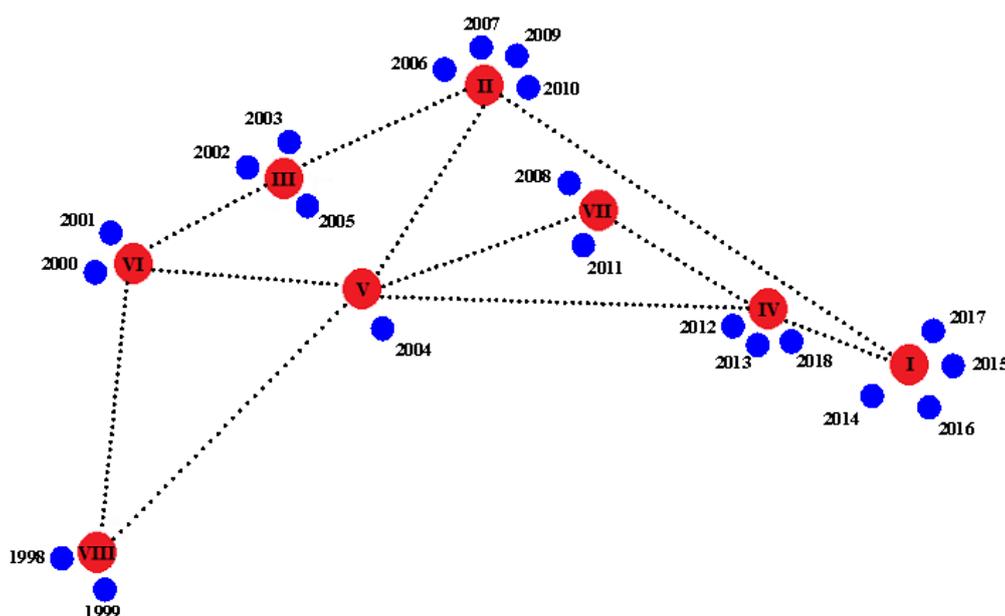
	MA	0.4		EV	0.2		GH	0.4
	EV	0.4		GH	0.3		FC	0.2
	GH	0.6		FC	0.2		PC	0.2
	FC	0.4		PC	0.1		SS	0.3
	PC	0.2		SS	0.2		TC	0.4
	SS	0.4		TC	0.2		DP	0.3
	TC	0.5		DP	0.2		HC	0.3
	DP	0.3		HC	0.3		AT	0.3
	HC	0.4		AT	0.1		CP	0.2
	AT	0.2		CP	0.0		SB	0.2
	CP	0.2		SB	0.1		PX	0.2
	SB	0.3		PX	0.1			
YI	PX	0.3	MA			EV		
	PX	0.3		SB	0.3		CP	0.2
							SB	0.3
SB			CP	PX	0.3	AT	PX	0.4
	FC	0.4		PC	0.3		SS	0.3
	PC	0.2		SS	0.4		TC	0.5
	SS	0.4		TC	0.6		DP	0.4
	TC	0.6		DP	0.4		HC	-0.1
	DP	0.4		HC	0.5		AT	0.2
	HC	0.5		AT	-0.1		CP	0.9
	AT	0.3		CP	0.3		SB	0.3
	CP	0.2		SB	0.4			
	SB	0.3		PX	0.3		PX	0.3
GH	PX	0.4	FC			CP		
	AT	0.3				HC		0.4
						AT		0.5
	CP	-0.2				CP		0.4
	SB	0.3				SB		0.5
HC	PX	0.3			DP	PX		0.4
	TC	0.6				DP		0.7
	DP	0.4				HC		0.5
	HC	0.4				AT		0.6
	AT	0.4				CP		0.6
	CP	0.3				SB		0.6
	SB	0.3				PX		0.6
SS	PX	0.3			FC			

\* year of genotype launch (YI), genotype maintainer (MA), biotechnological event present in the genotype (EV), growth habit (GH), flower color (FC), pod color (PC), seed shape (SS), tegument color (TC), density of pod pubescence (DP), seed hilum color (HC), anthocyanin in the seedling hypocotyl (AT), color of pod pubescence (CP), seed brightness (SB), peroxidase activity (PX).

The fragmented correlation (Table 2) was intended to explain the trend of the agronomic ideotype of the cultivar. Where cultivars with RR biotechnological events tend to have hilum with brown and black coloring, medium brown colored pod. Cultivars with an intact biotechnological event tend to indeterminate growth habit, have purple flowers, light brown pubescence color, imperfect black hilum, presence of anthocyanin in hypocotyls and low pod's pubescence density. Cultivars that reveal a purple color are mostly yellow tegument, the pubescence of the pod is light brown, the seed hilum is imperfect black, has anthocyanin in the hypocotyls and has flowers. Cultivars that reveal white flowers tend to lack anthocyanin in the hypocotyls, have peroxidase reactivity and the pods are gray to medium dark in color.

**Predictor Model for the Launch of New Cultivars in Brazil.** In order to reveal which attribute of the soybean chain, a multiple regression was used to enable the selection of which independent variable directly influenced the launch of new cultivars. In this way, the character, number of genotypes launched per year as dependent was fixed and the model with 68 independent characteristics was simulated, later it was identified that the export of grains in millions of tons determines the magnitude of cultivars launched per agricultural year. With future perspectives, it is identified that the exportation will be increased in a proportion of 1.9% to the agricultural year, and in 2050 it is estimated exports close to 100 million tons per year based on favorable scenarios in the soybean production chain. Thus, in the last two decades, we obtained a 65% increase in the launch of new cultivars (1998 to 2020). The future prospects for the launch of new cultivars based on grain exports indicate that in 2030 we will have an average launch of 184 cultivars per year, with an increase of 25%. In 2050, based on positive scenarios of the production chain to meet the internal and external demand for soybeans, it will be necessary for 274 cultivars to be launched each year so that Brazil has the correct positioning of specific genotypes for different environments.

Based on the artificial neural network with unsupervised computer learning, it was shown that the 68 characters measured in the 1818 soybean genotypes form distinct profiles, which are represented by the centroid (Figure 2). Thus, in the years 1998 and 1999 the import rate of grains was higher than production and exports, the same occurred in the 2000s. In 2001, with the significant increase in production, it resulted in a fall in imports. This fact, that in the year of 2002 the export gained greater prominence and resulted in a positive increase greater than the import. Between the years 2006 to 2010 it originated, that, the greater the production and the export the smaller the import of grains. Thus, the same results occurred in the following years between 2012 and 2018, but with the production in greater evidence according to the years of research. In the same way, exports also showed positive gains and the import of grains remained in a smaller proportion according to the years of research.



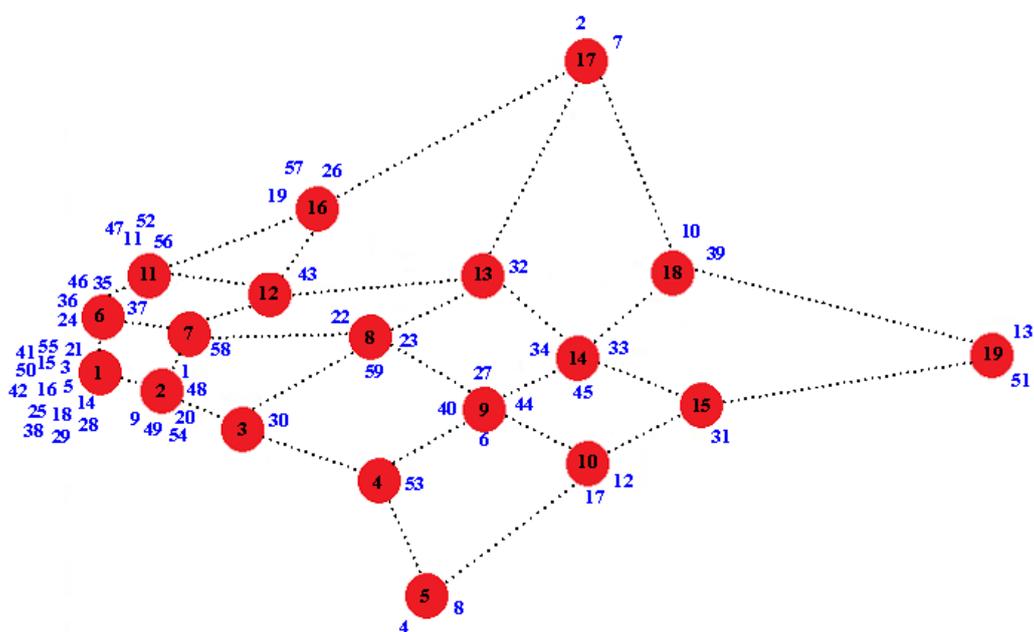
**Figure 2. Artificial Neural Networks (ANNs) obtained by the Kohonen Map defining the centroides (red) and the neurons of interest (blue) and the synaptic connections (blue lines), these being: 1998,1999, 2000,2001,2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018.**

In the years 1998 and 1999, the production of soybean seed was more prominent than grains destined for human and animal food, the same occurred in the years 2000 and 2001, but in a way that grains destined for animal feed would lose space in the year 2002 for grains intended for human consumption. From the year 2012 until 2018, gains remained for seed production and human food, while for grains destined for animals it remained stable.

The soybean sown area increased in the research years 1998 and 1999. The same happened in the following years, 2000 and 2001. Between the years 2002 and 2005 there was an increase in grain yield, which surpassed the registered genotypes. In years from 2006 to 2010 the larger the soybean sown area, the greater the grain yield and genotypes recorded. This event, which according to the years related to the research, between the years 2012 to 2018, the sown land area of soybean resulted in expansion and also the positive increase in grain yield followed by the increase of registered genotypes.

Related to technologies Conventional, Cultivance®, IPRO®, Liberty Link®, and Roundup Ready®, it was found that in the years 1998 and 1999, the decrease in Cultivance® technology and IPRO® technology began. However, Roundup Ready® technology leveraged the market while Conventional technology remained stable. In the years 2000 and 2001, Cultivance® still stood out, but in regression and the increase in Roundup Ready® technology. The years 2003 and 2005 were essential for Roundup Ready® technology, where it surpassed Cultivance® technology, the same happened for IPRO® technology, which started to stand out in the market. Between 2006 and 2010, there was the success of Roundup Ready® technology, surpassing other technologies and also by the significant increase that Liberty Link® technology began to have. The years 2012 to 2018 resulted in the expressive gain of IPRO® technology being superior to Roundup Ready®.

Based on the artificial neural network with unsupervised computer learning, it was shown that the 1818 soybean genotypes form distinct profiles, which are represented by the centroid (Figure 3), in order to identify which variables respond similarly. Thus, the 68 characters present 19 trends and the main ones are represented below by: **-Centroide 8: 22** (Seeds with yellow tegument), 23 (Seeds with light brown tegument) and, 59 (Pod with medium pubescence density). **-Centroide 17: 2** (Grain yield per hectare), 7 (Grains intended for animal feed). **-Centroide 18: 10** (Annual cultivar release rate), 39 (Seed with imperfect black hilum). **-Centroid 14: 34** (Seed with



**Figure 3. Artificial Neural Networks (ANNs) obtained by the Kohonen Map defining the centroides (red) and the neurons of interest (blue) and the synaptic connections (blue lines), these being: 1998, 1999, 2000,2001,2002, 2003, 2004, 2005, 2006, 2007, 2008,2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018.**

- \* 1) Area sown with soybean (AREA); 2) Grain yield per hectare (YIELD); 3) Grain production (PROD); 4) Grain exports (EXPM); 5) Grain imports (IMPM); 6) Grains intended for human consumption (HFOOD); 7) Grains for animal feed (AFEED); 8) Production of soybean seeds (SEED); 9) Cultivars launched per year (NCLA); 10) Annual cultivar launch rate (ACLR); 11) Conventional genotypes (TCON); 12) Genotypes with Cultivance® technology (TCUV); 13) Genotypes with IPRO® technology (TINT); 14) Genotypes with Liberty Link® technology (TELL); 15) Genotypes with Roundup Ready® technology (TERR); 16) Determinate growth habit (DGH); 17) Indeterminate growth habit (IGH); 18) Semi-determinate growth habit (SDGH); 19) White flower color (FWHI); 20) White / purple flower color (FWP); 21) Purple flower color (FPUR); 22) Seed with yellow tegument (TYEL); 23) Seed with light brown tegument (TLB); 24) Seed with brown tegument (TBRO); 25) Seed with black tegument (TBLA); 26) Pod with gray pubescence (PGP); 27) Pod with light gray pubescence (PLGP); 28) Pod with brown pubescence (PBP); 29) Pod with light brown pubescence (PLBP); 30) Pod with dark brown pubescence (PDBP); 31) Pod with medium brown pubescence (PMBP); 32) Seed with black hilum (HBLA); 33) Seed with yellow hilum (HYEL); 34) Seed with gray hilum (HGRA); 35) Seed with brown hilum (HBRO); 36) Seed with light brown hilum (HLB); 37) Seed with dark brown hilum (HDB); 38) Seed with medium brown hilum (HMB); 39) Seed with imperfect black hilum (HIB); 40) Presence of anthocyanin in the hypocotyl (PRES); 41) Absence of anthocyanin in the hypocotyl (ABSA); 42) Negative peroxidase activity (PERN); 43) Positive peroxidase activity (PERP); 44) Peroxidase intermediate activity (PERI); 45) Seed with elongated shape (SELO); 46) Seed with elongated/flat shape (SEF); 47) Seed with rounded shape (SROU); 48) Seed with spherical shape (SSPH); 49) Seed with flat spherical shape (SFS); 50) Seed with elongated spherical shape (SES); 51) Seed with spherical oval shape (SSO); 52) Seed with high brightness (BH); 53) Seed with low brightness (BL); 54) Seed with medium brightness (BMED); 55) Bright seed (BBRI); 56) Matte seed (BMAT); 57) Pod with high pubescence density (DPHI); 58) Pod with low pubescence density (DPLO); 59) Glabrous pod (DPGL); 60) Pod with medium pubescence density (DPME); 61) Pod with gray color (CPGR); 62) Pod with light gray color (CPLG); 63) Pod with dark gray color (CPDG); 64) Pod with light color (CPL); 65) Pod with brown color (CPBR); 66) Pod with light brown color (CPLB); 67) Pod with dark brown color (CPDB); 68) Pod with medium brown color (CPMB).

gray hilum), 33 (Seed with yellow hilum), 45 (Seed with elongated shape). -**Centroide 5: 4** (grain export), 8 (soybean seed production). -**Centroid 10: 17** (Indeterminate growth habit), 22 (Seed with yellow tegument). - **Centroid 19: 13** (Genotypes with IPRO® technology) and 51 (Seed with spherical oval shape). Based on the artificial neural network with unsupervised computer learning, it was evidenced that the 1818 soybean genotypes are classified, 18 profiles: -Profile 1: 149 genotypes (8.20%), Profile 2: 6 genotypes (0.33%), Profile 3: 75 genotypes (4.13%), Profile 4: 123 genotypes (6.77%), Profile 5: 75 genotypes (4.13%), Profile 6: 26 genotypes (1.43%), Profile 7: 212 genotypes (11.67%), Profile 8: 72 genotypes (3.96%), Profile 9: 162 genotypes (8.91%), Profile 10: 165 genotypes (9.07%), Profile 11: 16 genotypes (0.88%), Profile 12: 145 genotypes (7.98%), Profile 13: 66 genotypes (3.63%), Profile 14: 139 genotypes (7.65%), Profile 15: 237 genotypes (13.03%), Profile 16: 16 genotypes (0.88%), Profile 17: 60 genotypes (3.30%), Profile 18: 74 genotypes (4.07%). Bearing in mind that soybean is a major global reference and one of the most important Brazilian commodities, it has made it a power in the agricultural sector and the Brazilian economy. And that explains the increase that the product makes in several sectors, production, export, production chain, population increase, industries, job creation. The current scenario of the soybean market is positive and attractive, due to the fact that agricultural years are good, applied with high innovative technologies that contribute significantly to the increase in the production of the product, and this reflects in increases in the economy. Through the benefit that soybean adds to economic income, the research on biotechnological events to increase production can be understood. This demonstrates greater incentives, studies and advanced investments in the product, which results in good future prospects in the agricultural sector for the coming years.

In general, the aspects according to each year of launch of the cultivars are in favor of the best performance of the crop. They are correlated in the following modifications: plant architecture, resistance, seed size, indeterminate growth habit, flower colors, pods, hilums, presence of anthocyanin, peroxidase, seed brightness, densities and registered genotypes. With neural networks it was possible to classify 1818 soybean genotypes, divided into 18 profiles, also based on the search for 68 characters presenting 19 trends. With the work it was concluded that the year of launch of the cultivar is associated with: the intrinsic characteristics of the maintainer of the cultivar, the biotechnological event, the characteristics of the growth habit and the colorations of the flower, of the seed pod and of the hypocotyl. As the forecast is that in the coming decades new cultivars will be launched in Brazil, a correct positioning of specific genotypes for different environments is needed.

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