ISSN 2176-2899

COMUNICADO TÉCNICO

104

Londrina, PR
August, 2022

Soybean yellow leaf disorder: disease or a particular nutritional imbalance?

César de Castro
Fábio Álvares de Oliveira
Adilson de Oliveira Junior
Ruan Francisco Firmano

Soybean yellow leaf disorder: disease or a particular nutritional imbalance?[1]

[1]**César de Castro**, agronomist, doctor in Soils and Plant Nutrition, researcher at Embrapa Soja, Londrina, PR, Brazil; **Fábio Álvares de Oliveira**, agronomist, doctor in Soils and Plant Nutrition, researcher at Embrapa Soja, Londrina, PR, Brazil; **Adilson de Oliveira Junior**, agronomist, doctor in Soils and Plant Nutrition, researcher at Embrapa Soja, Londrina, PR, Brazil; **Ruan Francisco Firmano**, agronomist, doctor in Soils and Plant Nutrition, Technological and Industrial Development (DTI-C) scholarship, CNPq/Embrapa Soja, Londrina, PR, Brazil.

Introduction

Each crop season is unique, with particular characteristics, mainly correlated to climatic events, over which we have little influence, or concerning the intensity of pest and disease attacks, among others, which can cause high financial and psychological impacts to farmers or even, crop failures.

With the advent of interactive media and, mainly, communication technologies by instant cell phone messages, sharing images of plants and crops with certain features differing from the normal pattern of development became very dynamic. Thus, any tiny or insignificant anomaly, even the ones restricted to a small grove, is often disclosed without any contextualization (e.g., the adopted of phytosanitary and nutritional management history). Consequently, an unrealistic increase in its scaling can occur, reinforced by subsequent posts about the same anomaly and, as if driven by a free-will algorithm, then it becomes the subject of the moment, until it is supplanted by posts of a new abnormality, sometimes equally irrelevant.

In general, the search for immediate guidance, in general, lacks the care of a good anamnesis to assist in the remote interpretation of most phenomena or events. Thus, like an organism with a will of its own, which from that moment on, with spontaneous generation and geometric progression, information spreads through different groups, as in the old story of the broken telephone game, in which is a traditional popular game in which a story (fact) changes as passed ahead, distorting the original scenario and impairing a better understanding of the problem.

A “problem” that fits that example very well is the soybean X-spot, also named **yellow leaf disorder**, or any regional synonym for the same symptom (Figures 1 to 4). It is characterized by yellowish spots or yellowish circular spots on the leaves, which can coalesce (Figure 4), often inducing the diagnosis of occurrence of some disease, or phytotoxicity caused by some agricultural input, or derived from some herbicide, or nutritional deficiency (Anomalia..., 2012; Clay, 2013). It is worth remembering that these symptoms are not new and have been occurring in different production environments in Brazil for at least 15 years.

Photos: Cesar de Castro.

Figure 1. Soybean leaves with different stages of evolution of yellow leaf disorder symptoms, Londrina, state of Paraná, season 2010/2011.

Photos: Cesar de Castro.

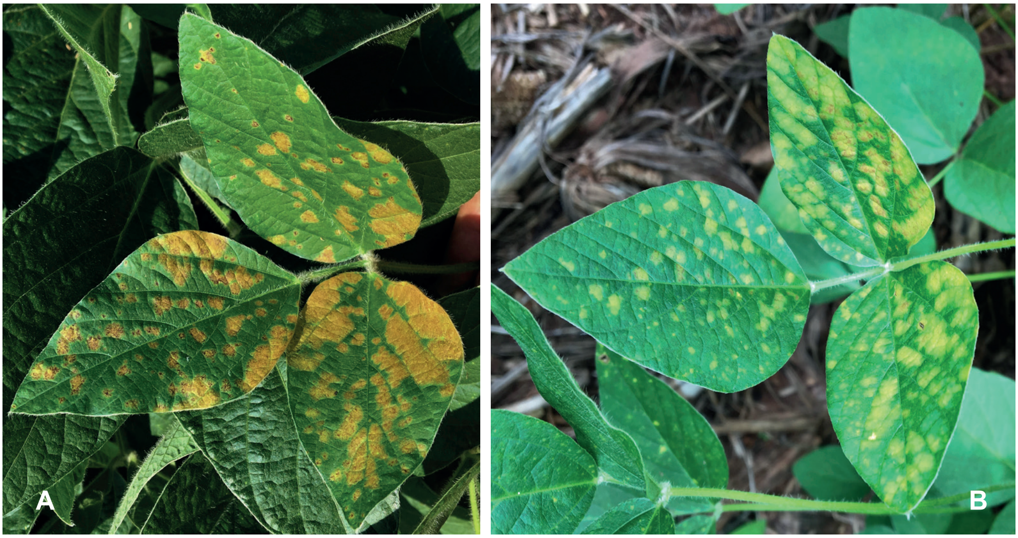

Figure 2. Soybean leaves with yellow leaf disorder symptoms observed in two distinct edaphoclimatic regions. **A.** Guapirama, state of Paraná; **B.** Nova Andradina, state of Mato Grosso do Sul.

Possibly, the first name adopted for this symptom was due to the lack of knowledge of the causal agent. As the symbol for the unknown quantity in mathematical equations, it was first named X-spot, and later called soybean yellow leaf disorder because of the initial symptoms. Similarly, other discoveries have also been named with the addition of the mathematical unknown “X”, equally due to the initial lack of knowledge of the phenomenon. Good examples are X-ray and X-Syndrome. In the first, dating from the end of the 19th century. The German scientist Wilhelm C. Röntgen used it due to the lack of knowledge about the nature of the light he had just discovered. For that scientist, it was an unknown ray, therefore an X-ray. In the 1980s, the name Syndrome X was used by Dr. Gerald M. Reaven to emphasize the fact, still relatively unknown, of the importance of insulin resistance as a factor in the risk of coronary heart disease (metabolic syndrome). Another example is the TV series, The X-Files, but this is another matter.

Those type of spots have been occurring for a long time in soybean crops, and it has been observed in several agricultural regions, in general, more frequently in areas with high yield potential. Since the symptom usually occurs on the leaves of poorly developed secondary branches, as if they were less productive or unproductive branches (Figure 3), mainly in the lower third of the plants, it is more easily observed when walking between the crop rows. That is, these leaves are hardly seen from a distance, and therefore the symptoms identification requires careful examination.

Photos: Cesar de Castro.

Figure 3. Soybean plants with yellow leaf disorder symptoms observed in two distinct edaphoclimatic regions. **A.** Palotina, state of Paraná; **B.** Londrina, state of Paraná.

Since the first appearance, the soybean yellow leaf disorder symptom was similar to the ones of the soybean target spot (*Corynespora cassiicola*). Researches in Brazilian institutes and universities studied the yellow leaf disorder to find a possible etiological agent (pathogen) triggering the typical symptoms in soybean leaves. Isolations were carried out in laboratories to identify an eventual pathogen. However, no fungi, viruses, or bacteria were detected associated with the symptom (Caju, 2012; Furlani, 2022).

Although the symptom occurs in different production environments, due to the initial similarity with the target spot and often associated with it, some farmers, fearing that the problem could spread, have mistakenly applied fungicides, increasing their production costs (Furlani, 2022).

In some particular situations, the symptoms of soybean yellow leaf disorder, initially characterized by isolated and small spots, can evolve and take up a large part of the leaflets. That can confuse an observer less familiar with the phenomenon, inducing the person to confound it with other problems, including nutritional issues. An example of a possible evolution of symptoms is in Figure 4, with coalescent spots resulting in interveinal yellowing or browning of the edges of soybean leaflets.

Photos: Fábio Alvares de Oliveira.

Figure 4. Soybean leaf with advanced symptoms of yellow leaf disorder observed in A. Rondonópolis, state of Mato Grosso and B. Ponta Grossa, state of Paraná.

Even though previously reported in agricultural media (Anomalia..., 2012; Caju, 2012; Furlani, 2022) and in observations of crops and experimental areas for a decade or more, it was not possible to associate the occurrence of yellow leaf disorder with losses of soybean yield. Therefore, the main objective with this document was to investigate the possible relationship between the characteristic symptoms of yellow leaf disorder and the mineral nutrition of soybean. Another more immediate aim was to help technicians and farmers to assess the real importance of these occurrences and their possible impact on soybean yield.

Material and Methods

How to solve the problem?

"Imagination is half the disease, reassurance is half the remedy, and patience and thoroughness are the first step towards healing or understanding the problem."

Modified from Abu Ibn Sina
(Avicena: 980-1037)

Considering that the problem appears sporadically and unexpectedly in different fields, agricultural regions, and soil types, conducting trials with experimental design, replications, and statistical interpretations is hardly feasible. Moreover, what would the treatments adopted be? Therefore, during the last seasons, we systematically collected soybean leaves and soil samples in different edaphoclimatic regions, commercial crops, and even in experimental areas conducted for other purposes, which arbitrarily presented the symptoms.

Subsequently, based on the first causal evidence, technical tours were made through different agricultural regions in various seasons. During those trips, a large number of samples were collected, mainly of leaves, whole plants, pods, grains and soils, as identified below:

- Leaves with symptoms randomly collected from soybean fields.
- Plants with and without symptoms.
- Leaves with and without symptoms collected from the same plants and at the same height and developmental position.
- Seeds collected from pods in the axils of leaves with symptoms on secondary stems and without symptoms on functional stems on the same plants and at the same height and developmental position.
- Soil samples from areas with plants exhibiting the problem.

The adopted strategy of surveying and collecting information, mainly in areas of commercial cropping areas and in different production environments, made it possible to isolate effects and better understand the problem. It also helped find a probable explanation and even some possible future research actions.

The soil samples were dried in an oven with forced air circulation (50°C) and sieved (2-mm mesh) for determination of pH using 0.01 mol/L $CaCl_2$; the organic carbon (OC) was extracted with potassium dichromate (Yeomans; Bremner, 1988). Potential acidity (H+Al) was estimated using the SMP buffer solution (Shoemaker et al., 1961); calcium (Ca), magnesium (Mg), and aluminum (Al) were determined using the extractant 1.0 mol/L KCl; and available potassium (K) and phosphorus (P) were determined using Mehlich 1 solution (Mehlich, 1954).

Plant tissues (leaves and grains) were digested (0.25 g) in 6 mL 65% HNO_3 v/v and 2 mL H_2O_2 in closed Teflon tubes. Wet digestion was performed in a microwave oven under the following conditions: 10 min heating, maintaining the temperature at 170°C for 15 min and cooling for 20 min to room temperature (USEPA, 1996). The equipment operated at 1600 W and 2 Mpa pressure. The extracts have their volumes adjusted with ultrapure water in 50 mL flasks. The determination of nitrogen (N), P, K, Ca, Mg, sulfur (S), boron (B), zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu) were carried out using inductively coupled plasma optical emission spectroscopy (ICP-OES).

Results and Discussion

The leaves with symptoms displayed chemical differences in relation to the leaves without symptoms in the same plant, at the same age, and located in the same position of the primary branch or in vigorous functional secondary branches. As seen in Table 1, symptomatic leaves are characterized by low concentrations of Ca and Mn, especially the former. That was unexpected, considering that the concentrations of Ca and Mn increase in leaves with the evolution of the phenological stages. In addition to such difference, the K concentrations found were slightly superior to those found in the leaves without symptoms or even in relation to the concentrations that would usually be present in soybean leaves.

Differently from the natural trend of the concentrations of Ca and Mn in the leaves until the end of the plant cycle, the concentration of K should decrease along the phenological stages due to the strong mobilization of this nutrient from the leaves to the grains. The highly negative correlation coefficient between Ca and K (r = -0.78), identified in soybean leaves, supports that finding. The best expression of the magnitude of K mobilization to the grains is the K amounts removed with the harvested grains. While one ton of grains removes around 18 kg of K, for Ca and Mn, 2.8 kg and 39 mg are removed, respectively (Oliveira Junior et al., 2020).

The leaves in branches where yellow leaf disorder occurs, develop below the soybean canopy, in a shaded environment, and with less photosynthetic activity; they are smaller, more tender, and less turgid. These leaves have lower sink strength, a function dependent on two factors: the size of the sink and the sink activity. Thus, the leaves, throughout their development, are sinks and later become sources of nutrients and photoassimilates. These leaves may have a lower capacity to absorb Ca and, particularly, a higher accumulation of K. However, as shown in Table 2, there is almost no variation in the concentrations of these nutrients in the grains formed in the branches, either with or without symptoms. This behavior can perhaps be explained by the lower number of pods/grains in the branches bearing leaves with yellow leaf disorder and, therefore, a lower amount of nutrients.

In order of magnitude, the other nutrients are within the sufficiency range, and with the exception of Mn, without a constant trend. It is worthy of note that the leaves collected from plants at different developmental stages, generally at more advanced reproductive stages (R3 or later), are not comparable to the nutrient concentration patterns of the foliar diagnosis using leaves collected at R2/R3 stage (Oliveira Junior et al., 2020).

If a more characteristic and determinant nutritional constant for the soybean leaves with yellow leaf disorder could be generalized, it would be represented as:

Soybean yellow leaf disorder = $f\,(\uparrow K \text{ and} \downarrow Ca, \downarrow Mn)$

Table 1. Nutrient concentrations in soybean leaves WITHOUT and WITH symptoms of yellow leaf disorder, collected at different reproductive stages and seasons, in eleven edaphoclimatic regions in Brazil.

Region	Symptom	N	P	K	Ca	Mg	S	Zn	Mn	Fe	Cu	B
		g kg^{-1}						mg kg^{-1}				
1	Without	65.5	2.2	14.8	7.1	2.9	1.6	65.8	125	328	5.3	33.2
1	With	53.2	3.8	23.0	2.9	3.7	1.6	64.0	104	170	8.7	49.7
2	Without	43.8	3.1	13.8	19.6	5.6	2.7	64.9	76	172	5.8	48.1
2	With	52.0	4.8	24.3	3.4	3.8	2.8	62.4	37	143	11.8	70.0
3	Without	45.7	2.6	12.7	11.4	4.9	2.6	40.8	160	125	7.4	33.5
3	With	50.2	3.5	20.7	4.8	4.3	2.5	45.3	94	152	9.4	47.4
4	Without	35.8	3.4	18.5	10.8	3.5	2.6	71.3	89	100	9.8	25.4
4	With	45.0	4.3	22.7	4.2	3.2	3.0	63.1	70	115	11.6	27.6
5	Without	35.2	2.4	16.8	12.6	2.8	2.4	48.7	215	132	6.8	28.6
5	With	40.4	3.5	23.7	7.7	3.3	2.5	47.3	125	168	9.7	26.9
6	Without	41.6	2.8	16.8	14.1	2.9	3.2	22.5	34	100	41.1	53,3
6	With	40.6	2.8	20.5	6.0	2.4	2.7	21.5	26	98	61.1	49,6
7	Without	33.8	2.4	18.0	14.2	3.1	2.2	42.6	234	134	5.3	28.2
7	With	36.7	3.2	23.6	6.1	3.3	2.1	38.0	118	140	8.1	24.8
8	Without	38.6	2.3	15.8	9.8	2.2	2.0	27.6	52	310	9.7	38.2
8	With	39.6	2.7	20.0	3.2	2.6	1.6	29.7	35	306	10.1	50.4
9	Without	30.1	2.7	15.3	13.5	2.4	1.7	16.8	28	103	36.6	32.8
9	With	36.7	2.4	18.5	7.1	2.5	1.8	15.2	29	127	22.2	33.4
10	Without	31.1	2.6	10.9	20.1	3.3	1,8	62.2	143	99	3.7	34.7
10	With	30.5	2.7	22.0	8.9	2.1	1.9	29.9	51	149	3.9	43.2
11	Without	20.6	2.3	17.4	9.9	2.8	3.9	40.0	106	165	6.2	39.5
11	With	20.1	2.9	21.1	2.7	3.7	3.9	42.6	48	199	8.0	47.9
Pattern*		**45-65**	**2.8-4.5**	**18-25**	**6-10**	**2.8-5.0**	**2.4-4.0**	**30-45**	**70-150**	**90-180**	**6-12**	**40-60**

*Nutrient concentration normally found in soybean leaves at the R2/R3 stage of development. (Oliveira Junior et al., 2020).

1: Campo Novo do Parecis, state of Mato Grosso; 2: Rondonópolis, state of Mato Grosso; 3: Londrina, state of Paraná; 4: Guapirama, state of Paraná; 5: Wenceslau Braz, state of Paraná; 6: Japira, state of Paraná; 7: Ponta Grossa, state of Paraná; 8: Rio Brilhante, state of Mato Grosso do Sul; 9: Ponta Porã, state of Mato Grosso do Sul, 10: Nova Mutum, state of Mato Grosso; 11: Palotina, state of Paraná.

In order to have an overview of the distribution of agricultural areas with symptoms of soybean yellow leaf disorder in Brazil, Figure 5 shows the location of the municipalities where samples of soybean leaves with and without symptoms were collected, corresponding to the analyses presented in Table 1.

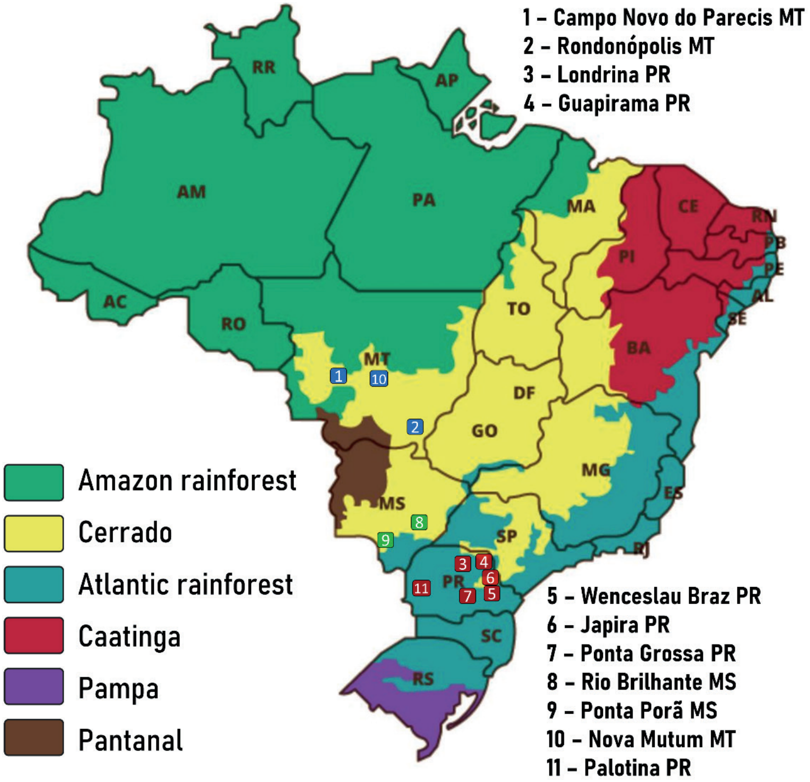

Figure 5. Map of Brazil with biomes and locations of municipalities where samples of soybean leaves with and without symptoms of soybean yellow leaf disorder were collected.

With these observations in mind, it becomes temptingly imaginable that the possible “solution” is to increase the availability of Ca to plants using the simplest, most unusual, or even the most innovative method. However, this action will be ineffective for eliminating the symptoms and only result in increased production costs.

Soybean yellow leaf disorder does not have a regular or expressive distribution in the crops, nor is it fully understood by professionals. Therefore, no management or technological action can be safely recommended, especially concerning fertilization, correction of soil acidity, or any others. Nutritional disorders have some characteristics or patterns such as i) onset of symptoms in leaves of the same physiological age; ii) progression of severity over time; iii) symmetry and distribution gradient in leaf blades; and iv) general distribution in the field (Marschner, 2012). These characteristics help differentiation among disorders, biotic or abiotic. Nevertheless, soybean yellow leaf disorder symptoms have caused a mixture of surprise and strangeness. Despite the imbalance between Ca and K associated with the symptoms, the appearance of the soybean yellow leaf disorder on a few leaves unevenly distributed in the crop, does not fit what would be expected in a nutritional problem. Thus, further studies and investigations are necessary to better explain such particular symptoms in soybean leaves.

Another point that raises doubts is whether the few seeds formed in pods on the branches with leaves showing these symptoms have different nutrient concentrations than those in the branches with non-symptomatic leaves. Table 2 shows two analyses of grains collected from edaphoclimatic region 3, Londrina, state of Paraná (Table 1).

Table 2. Nutrient concentrations in soybean seeds collected from branches with leaves WITHOUT and WITH symptoms of yellow leaf disorder in Londrina, state of Paraná.

Symptom	N	P	K	Ca	Mg	S	Zn	Mn	Fe	Cu	B
	$g\ kg^{-1}$						$mg\ kg^{-1}$				
Without	66.7	5.2	20.3	2.0	2.2	3.1	45.5	37.2	79.4	11.6	37.9
With	68.9	4.8	19.8	1.9	2.2	3.1	42.3	38.7	60.0	8.8	28.8
Pattern*	54.0	4.8	18.0	2.8	2.5	2.8	41.0	39.0	65.0	11.5	31.0

* Typical nutrient concentrations normally found in soybean seeds at the final stage of development (R8, full maturity), base moisture 13% (Oliveira Junior et al., 2020).

Even though the seeds were harvested before their physiological maturity and knowing the differences in the speed of nutrient translocation from leaves to seeds, in general, the nutrient concentrations are compatible with the pattern obtained at full maturation (R8) (Fehr; Caviness, 1977). The lower concentrations of Ca in the seeds can be explained by the high source/sink ratio, in other words, the increasing accumulation of this nutrient in leaves until the end of the soybean cycle, and its scanty translocation to seeds. Therefore, when harvested before physiological maturity, the immature seeds display Ca concentrations lower than expected in mature soybean seeds.

Regardless of the nutrient concentrations in the seeds harvested from branches with yellow leaf disorder, they generally have few pods and seeds compared to the main stem or vigorous functional branches. Given that yellow leaf disorder usually appears on weak branches and in a reduced number of plants randomly distributed in the fields, it is expected that the anomaly does not cause a decrease in the physiological quality or nutritional density of the produced seeds.

Another question is if the soil where the plants showed the described symptoms is deficient in C, or does it have an imbalance between the exchangeable cations of basic character (Ca/Mg/K)? Also, does the soil present any determinant characteristic that indicates a direct and causal relationship between its nutrient contents and soybean yellow leaf disorder on specific leaves in branches of the lower third of some plants?

In an attempt to shed some light on the questions of the previous paragraph, in Table 3 are presented the results of soil analysis from crops distributed in the traditional soybean production regions where, despite the normal development of the plants and apparent high soybean yield potential, we identified plants with symptoms of the soybean yellow leaf disorder.

Table 3. Analysis of soil samples collected in soybean fields containing plants with leaves presenting yellow leaf disorder, in different seasons, in ten edaphoclimatic regions in Brazil.

Region	pH	H+Al	Ca^{2+}	Mg^{2+}	K^+	SB	CEC	BS	OC	S	P
	$CaCl_2$	------------------------cmolc dm^{-3}------------------------						%	g dm^{-3}	----mg dm^{-3}----	
1	4.99	1.83	2.65	0.92	0.18	3.75	5.57	67	15.6	10.9	11.5
2	5.05	2.05	2.83	1.64	0.15	4.62	6.67	69	8.84	9.5	9.41
3	5.35	4.90	4.50	1.67	0.82	6.70	11.89	56	17.5	13.6	35.9
4	5.95	1.95	4.48	3.07	0.57	8.12	10.08	81	28.3	16.4	60.3
5	6.25	2.43	5.39	1.21	0.36	6.95	9.38	74	16.1	5.1	83.3
6	6.25	2.33	4,46	1.59	0.35	6.40	8.45	76	12.5	3.1	125.2
7	4.85	3.85	3.05	1.13	0.47	4.64	8.49	54.9	-	12.7	4.3
8	4.94	4.16	4.60	2.20	0.65	7.50	11.30	64	12.9	11.9	17.5
9	4.88	2.18	4.63	1.24	0.14	6.01	8.19	73	20.2	10.1	19.5
10	5.19	2.02	2.99	1.41	0.14	4.54	6.56	69	18.4	-	5.8

1: Campo Novo do Parecis, state of Mato Grosso; 2: Rondonópolis, state of Mato Grosso; 3: Londrina, state of Paraná; 4: Guapirama, state of Paraná; 5: Wenceslau Braz, state of Paraná; 6: Japira, state of Paraná, 7: Ponta Grossa, state of Paraná; 8: Rio Brilhante, state of Mato Grosso do Sul; 9: Ponta Porã, state of Mato Grosso do Sul; 10: Nova Mutum, state of Mato Grosso.

It is not possible or evident to find any recurring characteristic or basic problem that indicates a cause-and-effect relationship between the results of soil analyses (Table 3) and the concentrations of macronutrients in the leaves. The micronutrient concentrations in these samples were above the critical and characteristic levels of management of soybean crops cultivated in soils with high fertility (Oliveira Junior et al., 2020).

According to the information extracted from Table 3 about the contents of the three basic cations, the ratios Ca/Mg, Ca/K, and Mg/K (Table 4) are, in general, within the equilibrium range considered “desirable” or, at least, in the ranges normally found in most agricultural soils with high productive potential. Observing the percentage of Ca, Mg, and K occupation in the cation exchange capacity (CEC), most of the values can be considered normal or peculiar in soybean areas, without a causal relationship of imbalance that justifies the manifestation of symptoms on some plant leaves.

Table 4. Relationships between basic cations and percentage in the CEC of ten soils collected in 10 edaphoclimatic regions of Brazil from areas with crops exhibiting leaves with soybean yellow leaf disorder.

Region	Layer	Ratios			% CEC		
	cm	Ca/Mg	Ca/K	Mg/K	Ca	K	Mg
1	0-20	2.9	14.7	5.1	47.6	3.2	16.5
2	0-20	1.7	18.9	10.9	42.4	2.2	24.6
3	0-20	2.7	5.5	2.0	37.8	6.9	14.0
4	0-10	1.5	7.9	5.4	44.4	5.7	30.5
5	0-10	4.5	15.0	3.4	57.5	3.8	12.9
6	0-20	2.8	12.7	4.5	52.8	4.1	18.8
7	0-20	2.7	6.6	2.4	35.9	5.5	13.2
8	0-20	2.1	7.1	3.4	40.7	5.8	19.5
9	0-20	3.7	33.1	8.9	56.5	1.7	15.1
10	0-20	2.1	21.4	10.1	45.6	2.1	21.5
Ratios*		2.0-3.2	10-20	4-10	35-50	2.5-4.0	12-22

1: Campo Novo do Parecis, state of Mato Grosso; 2: Rondonópolis, state of Mato Grosso; 3: Londrina, state of Paraná; 4: Guapirama, state of Paraná; 5: Wenceslau Braz, state of Paraná; 6: Japira, state of Paraná; 7: Ponta Grossa, state of Paraná; 8: Rio Brilhante, state of Mato Grosso do Sul; 9: Ponta Porã, state of Mato Grosso do Sul; 10: Nova Mutum, state of Mato Grosso.

*Source: Oliveira Junior et al. (2020).

Based on the results shown in Tables 3 and 4, it is possible to observe, in some areas, the need for better management of soil acidity or fertilization, but this is not the object of discussion in this publication. Even so, it is impossible to affirm, in a peremptory way, that these factors or a possible isolated factor caused these particular occurrences in some plants, which have leaves with and without symptoms, in commercial crops, with phytosanitary and soil management compatible with any other commercial crops.

Another recurring issue concerns the question of whether there is or not a direct relationship between this symptom and the soybean cultivar. It is possible to affirm that this symptom occurs in leaves of unvigorous, little lignified and prostate branches in the lower third of the plant, containing few pods (less productive) (Figure 3). Consequently, this symptom has not been observed yet in single-stemmed cultivars, and its visualization in leaves with functional lateral branches is quite limited.

To better understand these symptoms, it is necessary to carry out more observations in commercial crops or even in experimental areas conducted with different purposes and to develop specific actions of complementary research, which could better elucidate a potential genetic relationship with this phenomenon.

Final Considerations

- Despite the wide distribution of the anomaly in the Brazilian main soybean-producing regions, it is restricted to a few leaves of smaller size, and in some plants in the fields. Therefore, it is still considered a minor or unimportant problem for farmers.
- Generally, the leaves with these spots are observed in soybean plants with normal development and crops with high yield potential.
- In plants that have leaves with symptoms of yellow leaf disorder, the other leaves located on functional branches have adequate concentrations of Ca and K, as well as other nutrients.
- The contents of Ca, K, and other nutrients in the soil where soybean plants have these spots are generally adequate or within the standards usually found in commercial crops.
- The management of soil acidity and fertilization complies with the fertility management standards for high yields.
- At the surveys in crops and experimental areas in different production environments, no soybean yield losses were observed due to the occurrence of yellow leaf disorder.
- Despite the different regional names used to characterize the symptom, the most convenient is to standardize

a common name for this disorder: soybean yellow leaf disorder.

- Finally, **only the leaves with yellow leaf disorder** have an imbalance between Ca, K, and Mn concentrations.

References

ANOMALIA causa confusão nas lavouras de soja do Cerrado. **Jornal Dia de Campo**, Apr. 11, 2012. Available at: http://www.diadecampo.com.br/zpublisher/materias/Materia.asp?secao=Pacotes%20Tecnol%F3gicos&id=26343. Acessed on: July 8, 2022.

CAJU, J. TMG alerta sobre sintomas de mancha aureolada. **Cultivar**, Apr. 2, 2012. Available at: https://revistacultivar.com.br/noticias/tmg-alerta-sobre-sintomas-de-mancha-aureolada. Acessed on: July 8, 2022.

CLAY, S. A. Soybean herbicide injury. In: CLAY, D. E.; CARLSON, C. G.; CLAY, S. A.; WAGNER, L.; DENEKE, D. L.; HAY, C. H. (ed.). **iGrow Soybeans**: best management practices for soybean production. Brookings: South Dakota State University, 2013. chap. 32, p. 254-265. (SDSU Extension. Agronomy, Horticulture, and Plant Science Books, 2). Available at: https://openprairie.sdstate.edu/plant_book/2. Acessed on: July 8, 2022.

FEHR, W. R.; CAVINESS, C. E. **Stages of soybean development**. Ames: Iowa State University of Science and Technology, 1977. 11 p. (Special report, 80).

FURLANI, L. Conheça a mancha-aureolada na cultura da soja. **Dia Rural**, Mar. 1, 2022. Available at: https://diarural.com.br/conhecaa-mancha-aureolada-na-cultura-da-soja/. Acessed on: July 8, 2022.

MARSCHNER, P. **Marschner's mineral nutrition of higher plants**. 3rd ed. London: Elsevier, 2012. 651 p.

MEHLICH, A. **Determination of P, Ca, Mg, K, Na and NH_4 by North Carolina Soil Testing Laboratories**. Raleigh: University of North Carolina, 1954.

OLIVEIRA JUNIOR, A. de; CASTRO, C. de; OLIVEIRA, F. A. de; KLEPKER, D. Fertilidade do solo e avaliação do estado nutricional da soja. In: SEIXAS, C. D. S.; NEUMAIER, N.; BALBINOT JUNIOR, A. A.; KRZYZANOWSKI, F. C.; LEITE, R. M. V. B. de C. (ed.). **Tecnologias de produção de soja**. Londrina: Embrapa Soja, 2020. chap. 7, p. 133-184. (Embrapa Soja. Sistemas de Produção, 17).

SHOEMAKER, H. E.; McLEAN, E. O.; PRATT, P. F. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminum. **Soil Science Society of America Journal**, v. 25, p. 274-277, 1961.

USEPA - United States Environmental Protection Agency. **Soil screening guidance**: technical background document. 2nd ed. Washington, DC: Office of Solid Waste and Emergency Response, 1996.

YEOMANS, J. C.; BREMNER, J. M. A rapid and precise method for routine determination of organic carbon in soil. **Communications in Soil Science and Plant Analysis**, v. 19, p. 1467-1476, 1988.

Copies of this publication
can be obtained at:

Embrapa Soja
Rodovia Carlos João Strass, s/nº Acesso
Orlando Amaral, Distrito de Warta
Caixa Postal: 4006
CEP 86085-981
Londrina, PR
(43) 3371-6000
www.embrapa.br/soja
www.embrapa.br/fale-conosco/sac

1st edition
Digitalized PDF (2022).

MINISTRY OF
AGRICULTURE, LIVESTOCK
E FOOD SUPPLY

Local Publication Committee

President
Adeney de Freitas Bueno

Executive Secretary
Regina Maria Villas Bôas de Campos Leite

Members
Claudine Dinali Santos Seixas, Edson Hirose, Ivani de Oliveira Negrão Lopes, José de Barros França Neto, Liliane Márcia Mertz-Henning, Marco Antonio Nogueira, Mônica Juliani Zavaglia Pereira e Norman Neumaier

Editorial supervision
Vanessa Fuzinatto Dall´Agnol

Translation
Suzana Oellers, agronomist, Master in Agronomy

Bibliografic standardization
Valéria de Fátima Cardoso

Colection graphic project
Carlos Eduardo Felice Barbeiro

Desktop publishing
Marisa Yuri Horikawa

Cover photo
Cesar de Castro

Cover illustration
Ruan Francisco Firmano