Chemical characteristics and compatibility of mixtures at different agricultural application rates

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Abstract

Tank mixes are widely used to control weeds, fungi, insects, and nematodes to increase the control spectrum. However, little is known about the interactions that may occur due to the different types of formulations and products used. This study aimed to evaluate the interaction and compatibility between different classes of products (herbicides, fungicides, insecticides, biostimulants, foliar fertilizers, and adjuvants) on the physical-chemical parameters of sprays commonly used in farming. The concentration of the sprays was stipulated by adopting a spray volume between 100, 50, and 10 L ha^{-1} and the dose recommended by the manufacturers. The characteristics evaluated were physical compatibility (presence or absence of flocculation, sedimentation, phase separation, formation of lumps, oil separation, formation of crystals and cream, and foam formation) and chemical compatibility (pH and electrical conductivity). The products tested have different affinities with the adjuvants and it is not possible to generalize the recommendations. The physicochemical compatibility between products of different classes of action and the adjuvants evaluated is dependent on the rest period, with constant agitation being essential before and during application for Glifotal®, 2.4 D®, Smart Trio®, and B-Moly®, in addition to molecular incompatibility separation occurring between 5-30 min after preparation of syrup for 2.4 D®, Smart Trio®, B-Moly®, Fosert®, Glyphosate®, Zethamaxx®, Bravonil®, Engeo®, Completo®, Plant Start®, Smart Cooper®, Manni Plex cal mg®, Manni Plex k® and Smart Zn®. pH also has a strong influence in some mixtures of syrups where flocculation occurred for the products Bravonil®, Engeo®, Completo®, Plant Start®, Smart Cooper®, and Smart Zn®, as well as the formation of lumps due to the concentration for Engeo®, Completo®, Plant Start®, and Smart Cooper®. It is concluded that dosages, homogenization, interactions between molecules of the same or different classes, and physicochemical parameters such as pH and electrical conductivity influence the obtaining of compatible application grouts.

Keywords: agrochemicals, spray additives, surfactants, application technology, dilution, pulverization

Características químicas e compatibilidade de misturas em diferentes taxas de aplicação agrícola

Resumo

As misturas em tanque são muito utilizadas no controle de plantas daninhas, fungos, insetos e nematóides com o intuito de se aumentar o espectro de controle. Entretanto, pouco se conhece sobre as interações que podem ocorrer devido aos diferentes tipos de formulações e produtos utilizados. Este estudo teve por objetivo avaliar a interação e compatibilidade entre diferentes classes de produtos (herbicidas, fungicidas, inseticidas, bioestimulantes, fertilizantes foliares e adjuvantes) sobre parâmetros físico-químicos de caldas comumente utilizadas na lavoura. A concentração das caldas foi estipulada adotando-se volume de calda entre 100, 50 e 10 L ha^{-1} e a dose recomendada pelos fabricantes. As características avaliadas foram: compatibilidade física (presença ou não de floculação, sedimentação, separação de fases, formação de grumos, separação de óleo, formação de cristais e creme, e formação de espuma) e compatibilidade química (pH e condutividade elétrica). Os produtos testados apresentam afinidades diferentes com os adjuvantes não sendo possível generalizar as recomendações. A compatibilidade físico-química entre os produtos de diferentes classes de ação e os adjuvantes avaliados é dependente do período de repouso sendo fundamental a agitação constante antes e durante a aplicação para Glifotal®, 2.4 D®, Smart Trio® e B-Moly®, além da incompatibilidade molecular ocorrendo a separação entre 5-30 min após preparo de calda para 2.4 D®, Smart Trio®, B-Moly®, Fosert®, Glyphosate®, Zethamaxx®, Bravonil®, Engeo®, Completo®, Plant Start®, Smart Cooper®, Manni Plex cal mg®, Manni Plex k® e Smart Zn®. O pH também apresenta forte influência em algumas misturas de caldas onde houve a floculação para os produtos Bravonil®, Engeo®, Completo®, Plant Start®, Smart Cooper® e Smart Zn®, bem como, a formação de grumos pela concentração para Engeo®, Completo®, Plant Start® e Smart Cooper®. Conclui-se que dosagens, homogeneização, interações entre moléculas de mesma classe ou classes diferentes, parâmetros físico-químicos como pH e condutividade elétrica influenciam na obtenção de caldas de aplicação compatíveis.

Palavras-chave: agroquímicos, aditivos de calda, surfatantes, tecnologia de aplicação, diluição, pulverização

1. Introduction

Using chemical control by agricultural phytosanitary products is necessary to maintain productivity and profitability in large and small crops (Costa et al., 2020; Ribeiro et al., 2021). In this sense, the use of chemicals in mixtures requires attention, as the formation of complexes between products and adjuvants must be verified, ensuring the quality of application of the necessary products and the maintenance of ground or aerial sprayers (Fritz et al., 2014; Carvalho et al., 2016; Gandini et al., 2020).

Mixing products in the tank is a common practice by rural producers in all regions of Brazil and the world, representing 97% of cases in Brazil alone (Gazziero (2015). The quality of the application is due to the peaceful and harmonious interaction between adjuvants and agricultural pesticides (herbicides, fungicides, insecticides, etc.), which involves many physical, chemical, and physiological processes and there may be several variations in each condition assessed (Mendonça; Raetano, 2007; Popa et al., 2014).

When evaluating complex interactions between products, there may be an increase in synergism, addition, or reduction (antagonism) due to physicochemical incompatibilities regarding the efficiency of controlling the target pest (Costa et al., 2020). According to Rakes et al. (2016) and Cunha & Martins (2022), the ideal mixture is one in which the combination of classes (herbicides, fungicides, insecticides, etc.) promotes efficient control of the target, with low toxicity for subsequent crops. Interaction between mixtures can occur even when the combination of products presents certain physical compatibility. During this combination, there may be a reduction in the action of the molecules on the target (insect, fungus, nematode, or weed). Furthermore, in several cases, target populations are intensified where there is resistance against the molecules of the applied products (Belz et al., 2008; Queiroz et al., 2008; Ikeda, 2013; Petter et al., 2013).

Several studies have been carried out to evaluate the harmony between adjuvants and products of synthetic origin for agricultural use. Studies carried out by Maciel et al. (2010), Xu et al. (2011); Petter et al. (2013); Silva-Matte et al. (2014); Decaro Jr et al. (2015); Sasaki et al. (2015) and Costa et al. (2017) evaluate the interactions between spraying mixtures, in addition, they observe the interaction in physical-chemical properties such as surface tension, droplet spectrum, contact angle, pH, electrical conductivity (EC) and viscosity, which are parameters of the technology susceptible to the addition of adjuvants.

Researchers like Wolf et al. (2003); Silva et al. (2007) and Petter et al. (2012) discuss some adjuvants incorporated into mixtures where they can put spraying at risk. Observing the incompatibility between products, it is possible to observe the Formation of phases, Formation of flakes, precipitated material, and even build-up in the tank, bars, and spray nozzles. The formation of flakes and precipitated material can cause clogging of nozzles and filters in addition to contamination during the use of agricultural machinery. Furthermore, Petter et al. (2012) add that excessive clogging results in the loss of effectiveness of phytosanitary products due to the reduction in the amount of active ingredient that is not applied together with the drops of solute.

Physicochemical tests such as measuring pH and EC are important in determining the stability and solubility of phytosanitary mixtures. In general, EC is the ability to measure the conduction of electrical current in a syrup solution and pH is defined as the degree of alkalinity or acidity of a homogeneous solution without the formation of phases. In this sense, measuring these parameters is of fundamental importance where sanitary products can be easily degraded by hydrolysis in an alkaline environment, where there are a large number of formulations that are prepared in water (Petter et al., 2013). Water is capable of forming a buffer effect between the formulas and therefore tolerates some small variability in the medium (Kissmann, 1997).

As can be seen, studies that evaluate the interaction between products are essential for the agricultural sector, as it makes it possible to understand the interactions, avoiding errors, application problems, and costs of changing parts in sprayers and thus guaranteeing a homogeneous application throughout the crop. Still little is known about the physicochemical characteristics of a complex number of synthetic and natural products and molecules used in pest control, Schampheleire et al. (2009) and Silva-Matte et al. (2014) also address this concern in knowing the interactions between phytosanitary products.

Therefore, this study aimed to verify the chemical characteristics and the occurrence of incompatibility of mixtures of phytosanitary products at different application rates in agricultural use.

2. Materials and Methods

2.1 Experimental location

The trial was conducted in the municipality of Rio Verde, Goiás State, Brazil, by the company Pulveriza Soluções Agrícolas Ltda, between January 2023 and January 2024.

2.2 Agricultural treatments

The experiment was conducted in a completely randomized design in a factorial scheme with combinations of 2 adjuvants, 2 herbicides, 6 biostimulants, 10 fungicides, 5 foliar fertilizers, and 5 insecticides (Table 1). The experiments were carried out at an ambient temperature of 25 ºC ± 0.5, the syrups were evaluated using the static physicochemical compatibility method, obtaining descriptive tables regarding homogeneity/heterogeneity aspects. The syrups were visually evaluated for the presence or absence of flocculation, sedimentation, phase separation, formation of lumps, oil separation, formation of crystals, and cream and foam formation in the groats. The syrups were evaluated after 30 min of rest. Standard water with a total hardness of 20 mg kg^{-1} in $CaCO_3$ equivalent was used to prepare the syrups. The treatments consisted of 8 mixtures at application rates of 10, 50, and 100 L ha^{-1} (Tables 1 and 2).

Table 1. Order of adding syrup used in this experiment.

Order	Code	Name/description	Feature
1	WG	Water dispersible granules	Solids
2	WP	Wettable powder	Insoluble
3	CaS	Capsule suspension	Suspension
4	CS	Concentrated suspension	Suspension
5	OD	Oil dispersion	Suspension
6	SE	Emulsifiable suspension	Intermediaries
7	EC	Emulsifiable concentrate	Emulsions
8	EO	Water-in-oil emulsion	Emulsions
9	EW	Oil in water emulsion	Emulsions
10	ME	Microemulsion	Emulsions
11	SG	Water soluble granule	High solubility formulation
12	SP	Water soluble powder	High solubility formulation
13	SL	Soluble (liquid) concentrated	High solubility formulation

Source: Authors, 2024.

Table 2. Description of treatments with different mixtures of agricultural mixtures in terms of doses, functional classification, and formulation.

Treatments	Product	Dose	Functional classification	Formulation
1	Forset	0.05	Adjuvant	CS
1	Glyphosate	3.50	Herbicide	SL
1	2.4D	1.50	Herbicide	SL
1	Smart Trio	1.50	Biostimulant	CS
1	B-Moly	1.50	Foliar fertilizer	CS
2	Forset	0.05	Insecticide	CS
2	Glyphosate	3.50	Herbicide	EC
2	Zethamaxx	0.60	Fungicide	CS
2	Smart Trio	1.50	Fungicide	EC
2	B-Moly	1.50	Foliar fertilizer	CS
3	Actionsil	0.05	Adjuvant	CS
3	Bravonil	1.50	Fungicide	CS
3	Engeo Pleno	0.15	Insecticide	CS
3	Completo	1.00	Foliar fertilizer	CS
3	Plant Start	0.50	Biostimulant	CS
3	Smart Copper	0.40	Foliar fertilizer	CS
4	Actionsil	0.05	Adjuvant	CS
4	Fox Xpro	0.50	Fungicide	CS
4	Galil	0.35	Insecticide	CS
4	Completo	1.00	Foliar fertilizer	CS
4	Plant Start	0.50	Biostimulant	CS
4	Smart Copper	0.40	Foliar fertilizer	CS
5	Becatron	0.05	Adjuvant	CS
5	Evolution	1.75	Fungicide	WG
5	Fox Supra	0.35	Fungicide	CS
5	Manni Plex K	1.00	Foliar fertilizer	CS
5	Manni Plex Cal Mag	1.00	Biostimulant	CS
6	Becatron	0.05	Adjuvant	CS
6	Vessarya	0.60	Fungicide	EC
6	Krypto	1.00	Insecticide	EC
6	Manni Plex K	1.00	Foliar fertilizer	CS
6	Manni Plex Cal Mag	1.00	Biostimulant	CS
7	Actinsil	0.05	Adjuvant	CS
7	Sperto	0.30	Insecticide	WG
7	Abacus	0.30	Fungicide	CS
7	Complete	1.00	Foliar fertilizer	CS
7	Plant Start	0.50	Biostimulant	CS
7	Smart ZN	2.00	Biostimulant	CS
8	Boron 10%	1.00	Biostimulant	CS
8	Smart Quatro	1.50	Biostimulant	CS

Source: Authors, 2024.

For each mixture, water was previously analyzed as a solvent for all mixtures, allowing the pH and electrical conductivity (EC) to be characterized. The experiment was carried out in a 2 L beaker flask previously identified with the respective treatment, and the addition of products was carried out according to (Table 1). To calculate the product to be used in the beaker flask, formula (1) was applied:

$$PR = (CT*D) / Q \qquad (1)$$

Where: PR = is the product to be added to the beaker flask; CT = is the capacity of the beaker flask; D = corresponds to the dose of product per hectare (ha^{-1}), and Q = is the application rate in L/ha^{-1}.

2.3 Physicochemical characteristics of the syrups

The physicochemical characteristics of the grouts were evaluated as described by NBR 13875 (ABNT, 2015).

2.3.1 Determination of pH and electrical conductivity

The hydrogen potential was obtained using a previously calibrated digital pH meter using 250 mL of syrup. Electrical conductivity was determined using a digital conductivity meter and the results were expressed in (µS cm^{-1}) for water used to dilute the syrup and after mixing for each product and/or oil.

2.3.2 Determination of incompatibility of mixtures separation using granulometric sieves

The parameters of incompatibilities due to sedimentation, phase separation, lumps, oil, crystals, and cream after the addition of each product and/or oil were determined. At different times, the final pH for each syrup was evaluated after 30 min of rest. For immediate phase separation, results were obtained after 1, 10 and 30 min. To check for lumps and non-soluble particles “clogging in the sieves”, granulometric sieves with 50, 80, and 100 mesh were used.

3. Results

The mixtures in Table 3 were compatible between the products and adjuvant at acidic pH 4 and without phase separation.

Table 3. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Experiment	*Rate 10*	*Treatment*	*1*

Application Product	pH	100 EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Forset	6.63	321	No	No	No	No	No	No	No
Glifotal	4.79	4.93	No	No	No	No	No	No	No
2.4 D	4.82	7.46	No	No	No	No	No	No	No
Smart	3.92	8.90	No	No	No	No	No	No	No
B-Moly	4.44	9.35	No	No	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.44		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes ( )	No (x)	Separation - 5	Yes ( )	No (x)
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes ( )	No (x)	Separation- 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 4, the mixture between the products formed flocculation and sedimentation, except for water and Forset. The pH proved to be neutron with a value of 6 and there was no phase separation.

Table 4. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Product	pH	50 EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Água	7.67	316	No	No	No	No	No	No	No
Forset	5.87	347	No	No	No	No	No	No	No
Glifotal	4.70	963	Yes	Yes	No	No	No	No	No
2.4 D	5.28	1523	Yes	Yes	No	No	No	No	No
Smart	4.01	1523	Yes	Yes	No	No	No	No	No
B-Moly	6.69	1590	Yes	Yes	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	6.69		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes ( )	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 5, the final pH value is 4, demonstrating an acidic final mixture, with separation for 2.4 D, Smart and B-moly, with retention mesh 50.

Table 5. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Product	pH	10 EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.89	303	No	No	No	No	No	No	No
Forset	4.56	686	No	No	No	No	No	No	No
Glifotal	4.51	17.80	No	No	No	No	No	No	No
2.4 D	4.91	24.1	No	No	Yes	No	No	No	No
Smart	4.16	0	No	No	Yes	No	No	No	No
B-Moly	4.51	0	No	No	Yes	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes (x)	No ( )
Final pH syrup:	4.52		Separation - 1	Yes (x)	No ( )
Mesh 50:	Yes (x)	No ( )	Separation - 5	Yes (x)	No ( )
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

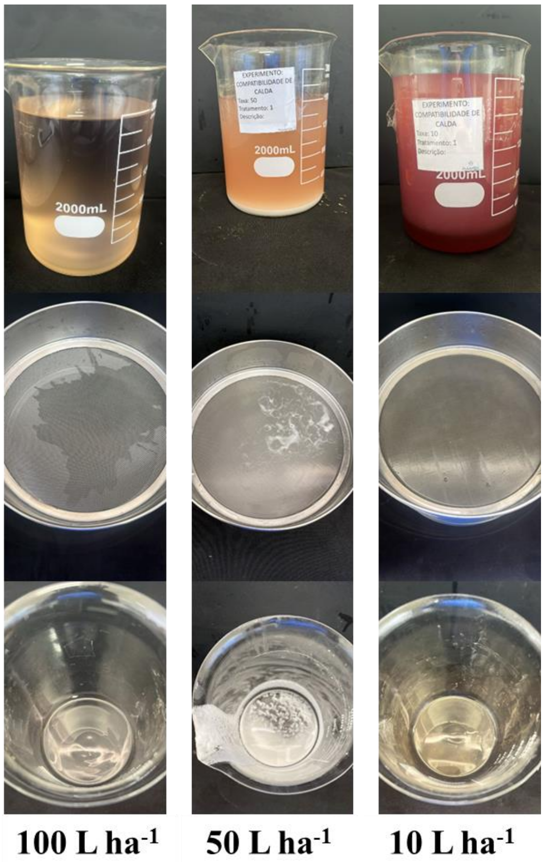


Figure 1. Forset + Glyphosate + 2.4D + Smart Trio+B-moly, Treatment 1. Source Authors, 2024.

In Table 6, the pH showed an acid value of 4, with phase separation in all mixtures and retention at mesh 50.

Table 6. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Experiment		*Rate 100*			*Treatment*		*2*		
Application Rate		100							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	Yes	No	No	No	No
Forset	6.60	313	No	No	Yes	No	No	No	No
Glyphosate	4.79	4.99	No	No	Yes	No	No	No	No
Zethamaxx	4.81	5.57	No	No	Yes	No	No	No	No
Smart Trio	3.74	6.78	No	No	Yes	No	No	No	No
B-Moly	4.45	7.35	No	No	Yes	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate separat:	Yes (x)	No ( )
Final pH syrup:	4.52		Separation - 1	Yes (x)	No ( )
Mesh 50:	Yes (x)	No ( )	Separation - 5	Yes (x)	No ( )
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 7, the final pH is acidic with a result of 4 without any change between the mixtures.

Table 7. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.87	308	No	No	No	No	No	No	No
Forset	5.17	382	No	No	No	No	No	No	No
Glyphosate	5.55	14.95	No	No	No	No	No	No	No
Zethamaxx	4.57	14.95	No	No	No	No	No	No	No
Smart trio	3.42	18.08	No	No	No	No	No	No	No
B-moly	4.22	14.39	No	No	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.22		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes ( )	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 8, the pH is acidic with a value of 4 and without any change between the mixtures.

Table 8. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		10							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.89	303	No	No	No	No	No	No	No
Forset	4.55	680	No	No	No	No	No	No	No
Glyphosate	4.56	17.9	No	No	No	No	No	No	No
Zethamaxx	4.61	21.2	No	No	No	No	No	No	No
Smart Trio	3.51	22.9	No	No	No	No	No	No	No
B-Moly	4.18	22.4	No	No	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes (x)	No ( )
Final pH syrup:	4.19		Separation - 1 min:	Yes (x)	No ( )
Mesh 50:	Yes (x)	No ( )	Separation - 5 min:	Yes (x)	No ( )
Mesh 80:	Yes (x)	No ( )	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

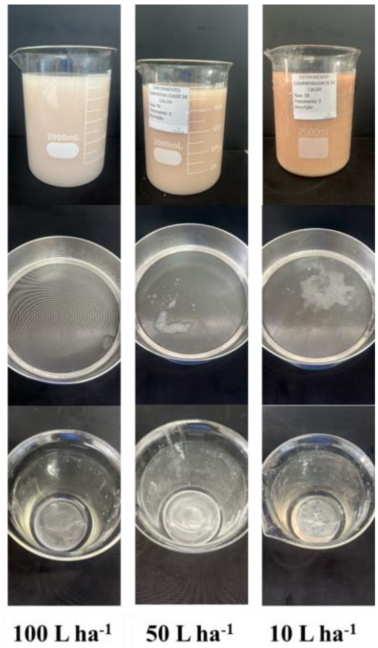


Figure 2. Forset + Glyphosate + Zethamaxx + Smart trio + B moly, Treatment 2. Source Authors, 2024.

In Table 9 Plant Start and Smart copper show separation with 10 and 30 min and with final syrup showing acidic pH 4.

Table 9. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment		*3*							
Application Rate		100							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	7.12	458	No	No	No	No	No	No	No
Bravonil	7.20	502	No	No	No	No	No	No	No
Engeo	7.21	513	No	No	No	No	No	No	No
Completo	2.61	6.45	No	No	No	No	No	No	No
Plant	4.23	8.14	No	No	Yes	No	No	No	No
Smart	4.54	8.70	No	No	Yes	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.54		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 10 there was flocculation and separation in all syrups, except for water and Actionsil with acidic pH 4 and oil.

Table 10. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	6.53	589	No	No	No	No	No	No	No
Bravonil	6.69	657	Yes	No	Yes	No	No	No	No
Engeo	6.74	681	Yes	No	Yes	No	No	No	No
Complete	2.42	1.070	Yes	No	Yes	No	No	No	No
Plant	4.25	1.455	Yes	No	Yes	No	No	No	No
Smart	4.54	1.519	Yes	No	Yes	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes (x)	No ( )
Final pH syrup:	4.53		Separation - 1 min:	Yes (x)	No ( )
Mesh 50:	Yes (x)	No ( )	Separation - 5 min:	Yes (x)	No ( )
Mesh 80:	Yes (x)	No ( )	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (x)	No ( )	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 11 there was the formation of lumps except for Actionsil and Bravonil, final pH 4 acid without separation for up to 30 min.

Table 11. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		10							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	Yes	No	No	No
Actionsil	6.22	1.278	No	No	No	No	No	No	No
Bravonil	6.31	1.479	No	No	No	No	No	No	No
Engeo	7.14	1.593	No	No	No	Yes	No	No	No
Completo	2.12	0	No	No	No	Yes	No	No	No
Plant Start	3.63	0	No	No	No	Yes	No	No	No
Smart	4.12	0	No	No	No	Yes	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.11		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes (x)	No ( )	Separation - 5	Yes ( )	No (x)
Mesh 80:	Yes (x)	No ( )	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (x)	No ( )	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

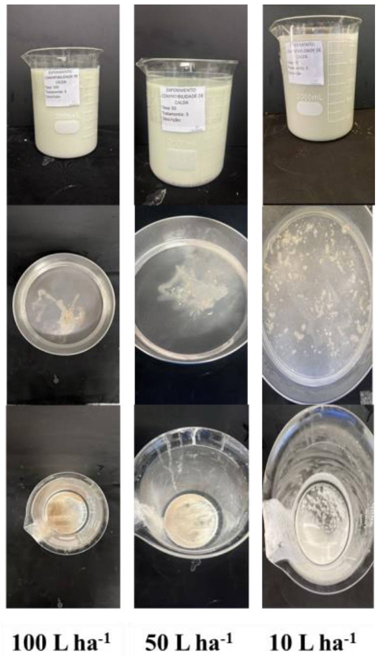


Figure 3. Actinosil + Bravonil + Engeo + Completo + Plant Start + Smart Copper, Treatment 3. Source Authors, 2024.

In Table 12 there was a separation for Completo, Plant Start, and Smart with an acidic pH equal to 4, with a separation between 10-30 min.

Table 12. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment			*4*						
Application Rate		100							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	7.28	456	No	No	No	No	No	No	No
Fox Xpro	6.70	426	No	No	No	No	No	No	No
Galil	6.85	424	No	No	No	No	No	No	No
Completo	2.55	632	No	No	Yes	No	No	No	No
Plant	4.27	771	No	No	Yes	No	No	No	No
Smart	4.45	729	No	No	Yes	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes (x)	No ( )
Final pH syrup:	4.46		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 13 there was separation only for Smart Cooper with acidic pH equal to 4 with separation between 10-30 min.

Table 13. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	PH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	7.28	588	No	No	No	No	No	No	No
Fox Xpro	6.25	517	No	No	No	No	No	No	No
Galil	6.29	558	No	No	No	No	No	No	No
Completo	2.36	1000	No	No	No	No	No	No	No
Plant	3.96	1132	No	No	No	No	No	No	No
Smart	4.20	999	No	No	Yes	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.21		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 14 there was no change between the mixtures, with acidic pH 4, with separation only after 30 min.

Table 14. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	6.80	1457	No	No	No	No	No	No	No
Fox Xpro	4.52	1322	No	No	No	No	No	No	No
Galil	4.53	1322	No	No	No	No	No	No	No
Completo	2.11	227	No	No	No	No	No	No	No
Plant	3.66	0	No	No	No	No	No	No	No
Smart	4.66	1670	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	4.27		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

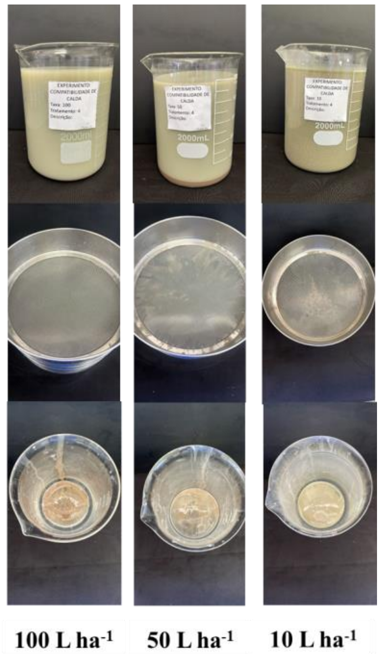


Figure 4. Actinosil + Foxxpro + Galil + Completo + Plant Start + Smart Copper, Treatment 4. Source Authors, 2024.

In Table 15 there was no change between the mixtures, with pH 8 slightly alkaline without phase separation.

Table 15. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment		*5*							
Application Rate		100							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.65	299	No	No	No	No	No	No	No
Evolution	7.37	2.63	No	No	No	No	No	No	No
Fox Supra	6.82	2.56	No	No	No	No	No	No	No
Manni plex	10.03	7.67	No	No	No	No	No	No	No
Manni plex	8.28	10.93	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	8.27		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

Table 16 there was no change between the mixtures, the pH 7 was slightly alkaline without phase separation and for a time of up to 30 min.

Table 16. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.54	4.22	No	No	No	No	No	No	No
Evolution	7.25	4.51	No	No	No	No	No	No	No
Fox supra	6.41	4.04	No	No	No	No	No	No	No
Manni	10.18	14.10	No	No	No	No	No	No	No
Manni	7.82	19.37	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	7.80		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

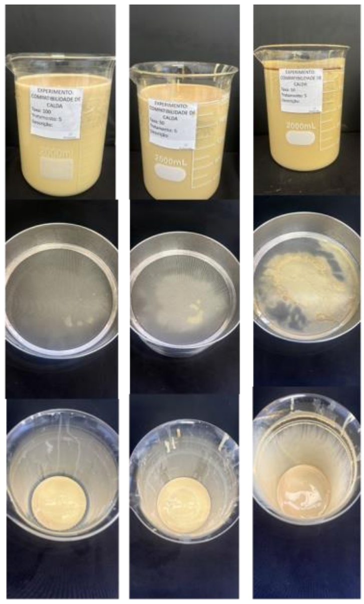
In Table 17 there was no change between the mixtures, with pH 7 slightly alkaline, however, there was separation after 30 min.

Table 17. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		10							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.54	4.22	No	No	No	No	No	No	No
Evolution	7.25	4.51	No	No	No	No	No	No	No
Fox Supra	6.41	4.04	No	No	No	No	No	No	No
Manni	10.18	14.10	No	No	No	No	No	No	No
Manni	7.82	19.37	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	7.19		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.



100 L ha^{-1} 50 L ha^{-1} 10 L ha^{-1}

Figure 5. Becatron + Evolution + Fox Supra + Manni Plex K + Manni Plex Cal Mag, Treatment 5. Source Authors, 2024.

In Table 18 there was no change between the mixtures, pH 9 was alkaline and separated with 10-30 min.

Table 18. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment	*6*									
Application Product	100 pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.88	296	No	No	No	No	No	No	No
Vessarya	7.79	290	No	No	No	No	No	No	No
Krypto	7.65	278	No	No	No	No	No	No	No
Manni plex k	11.07	6.92	No	No	No	No	No	No	No
Manni plex cal	9.60	9.89	No	No	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	9.60		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes ( )	No (x)	Separation - 5	Yes ( )	No (x)
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 19 there were no changes in the syrups, with alkaline pH 9 and no separation for up to 30 min.

Table 19. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application	50								
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.79	300	No	No	No	No	No	No	No
Vessarya	7.77	271	No	No	No	No	No	No	No
Krypto	7.70	212	No	No	No	No	No	No	No
Manni plex k	11.21	12.70	No	No	No	No	No	No	No
Manni plex cal	9.60	16.32	No	No	No	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	9.60		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes ( )	No (x)	Separation - 5	Yes ( )	No (x)
Mesh 80:	Yes ( )	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes ( )	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

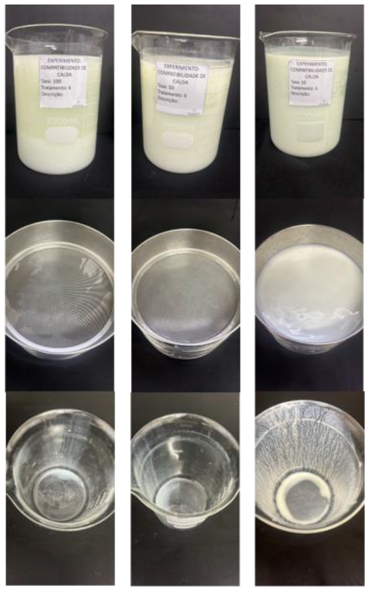
In Table 20, separation was observed for Manni plex and Manni plex cal mag with slightly alkaline pH 8 and without separation for up to 30 min.

Table 20. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application	10								
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Becatron	7.63	288	No	No	No	No	No	No	No
Vessarya	7.41	1580	No	No	No	No	No	No	No
Krypto	7.37	1700	No	No	No	No	No	No	No
Manni plex k	11.58	0	No	No	Yes	No	No	No	No
Manni plex cal	8.55	0	No	No	Yes	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	8.55		Separation - 1	Yes ( )	No (x)
Mesh 50:	Yes (x)	No ( )	Separation - 5	Yes ( )	No (x)
Mesh 80:	Yes (x)	No ( )	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (x)	No ( )	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.



100 L ha^{-1} 50 L ha^{-1} 10 L ha^{-1}

Figure 6. Becatron + Vessarya + Krypto + Manni Plex K + Manni Plex Cal Mag, Treatment 6. Source Authors, 2024.

In Table 21, no changes were observed between the mixtures, a very acidic pH equal to 2, and no separation for up to 30 min.

Table 21. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment	*7*									
Application Rate		100								
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream	
Water	7.80	300	No	No	No	No	No	No	No	
Actionsil	7.46	455	No	No	No	No	No	No	No	
Sperto	7.13	1172	No	No	No	No	No	No	No	
Abacus	7.09	1167	No	No	No	No	No	No	No	
Completo	2.65	672	No	No	No	No	No	No	No	
Plant	4.26	827	No	No	No	No	No	No	No	
Smart zn	2.41	1046	No	No	No	No	No	No	No	

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	2.41		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (x	No ( )	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (x	No ( )	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (x	No ( )	Separation - 30	Yes ( )	N0 (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 22, no changes were observed between the mixtures, pH 3 acid, and no separation for up to 30 min.

Table 22. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		50							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	7.26	646	No	No	No	No	No	No	No
Sperto	6.84	1810	No	No	No	No	No	No	No
Abacus	7.13	1173	No	No	No	No	No	No	No
Completo	6.89	1805	No	No	No	No	No	No	No
Plant	2.41	1252	No	No	No	No	No	No	No
Smart Zn	3.93	1515	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	3.94		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

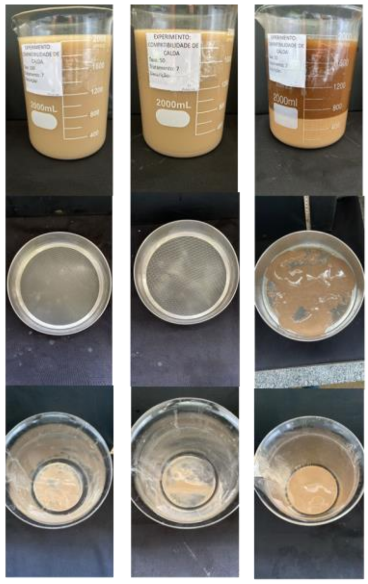
In Table 23 Smart Zn shown floculation, sedimentation, and separation with acidic pH3 and separation at all times.

Table 23. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate		10							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Actionsil	6.84	1,859	No	No	No	No	No	No	No
Sperto	6.22	659	No	No	No	No	No	No	No
Abacus	6.22	641	No	No	No	No	No	No	No
Completo	2.10	0	No	No	No	No	No	No	No
Plant	3.69	0	No	No	No	No	No	No	No
Smart Zn	3.69	0	Yes	Yes	Yes	No	No	No	No

Foaming:	Yes ( )	No (x)	Immediate	Yes (x)	No ( )
Final pH syrup:	3.69		Separation - 1 min:	Yes (x)	No ( )
Mesh 50:	Yes (x	No ( )	Separation - 5 min:	Yes (x)	No ( )
Mesh 80:	Yes (x	No ( )	Separation - 10	Yes (x)	No ( )
Mesh 100:	Yes (x	No ( )	Separation - 30	Yes (x)	No ( )

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.



100 L ha^{-1} **50 L ha^{-1}** **10 L ha^{-1}**

Figure 7. Actinosil + Sperto + Abacus + Completo + Plant Star + Smart ZN, Treatment 7. Source Authors, 2024.

In Table 24 there were no changes between the mixtures, pH 8 slightly alkaline, and no separation for up to 30 min.

Table 24. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Treatment	*8*								
Application Rate		100							
Product	pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Boron	8.92	346	No	No	No	No	No	No	No
Smart	8.66	622	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	8.67		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 25 there was no change between the mixtures, pH 8 slightly alkaline, and no separation for up to 30 min.

Table 25. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Product	50 pH	EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Boron 10%	8.90	489	No	No	No	No	No	No	No
Smart 4 plus	8.73	877	No	No	No	No	No	No	No

Foaming:	Yes (	No (x)	Immediate	Yes ( )	No (x)
Final pH syrup:	8.73		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (x)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (x)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	No (x)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.

In Table 26 there was no change between the mixtures, pH 8 slightly alkaline and no phase separation after 30 min.

Table 26. Physicochemical compatibility of mixtures of different agrochemicals registered for soybean and corn cultivation and tested according to criteria by ABNT [Associação Brasileira de Normas Técnicas (Brazilian National Standards Organization)] NBR [Norma Brasileira Regulamentadora (Brazilian Regulatory Standard)] (ABNT NBR 13875:2014). Temperature: 25 ºC; RH: 55 ± 10%, Rio Verde, Goiás, Brazil, 2024.

Application Rate Product	pH	10 EC	Flocculation	Sedimentation	Separation	Groats	Oil	Crystals	Cream
Water	7.80	300	No	No	No	No	No	No	No
Boron	8.80	1382	No	No	No	No	No	No	No
Smart	8.90	489	No	No	No	No	No	No	No

Foaming:	Yes (	No (X)	Immediate	Yes ( )	No (x)
Final pH syrup:	8.91		Separation - 1 min:	Yes ( )	No (x)
Mesh 50:	Yes (	No (X)	Separation - 5 min:	Yes ( )	No (x)
Mesh 80:	Yes (	No (X)	Separation - 10	Yes ( )	No (x)
Mesh 100:	Yes (	N0 (X)	Separation - 30	Yes ( )	No (x)

Note: Yes = positive; No = negative; pH = after stirring and EC = electrical conductivity. Source: Authors, 2024.
Source: Authors, 2024.

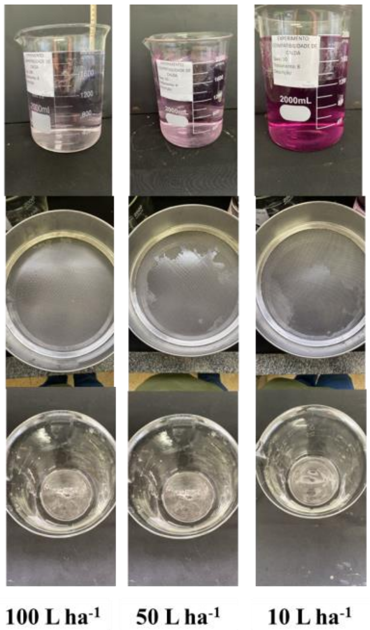


Figure 8. Boron 10% + Smart Quatro Plus, Treatment 8. Source Authors, 2024.

4. Discussion

Mixtures between different agents such as herbicides, fungicides, insecticides, biostimulants, foliar fertilizers, and adjuvants in our findings showed parameters of incompatibility of peaceful and harmonious interaction for some analyzed parameters and with acidic pH where greater stability of these compounds of different agricultural actions is found.

However, the configuration of the active molecule, pH, and EC among other physicochemical parameters may present non-harmonic interactions, which were described by Cunha & Martins (2022) between herbicides where the mixture with 2.4 D® + Imazetapyr® + Cletodim after preparation and with 2.4 D® + Diuron® + Flumioxazine® after 12 h are not recommended due to the presence of lumps and sedimentation. Our results with 2.4 D showed homogeneity at pH 4, however, at neutral pH 6 there was the formation of flocculation, sedimentation, and phase separation, which corroborates the influence of pH between the molecules. Corroborating these authors. Still in this study, the mixture with Glyphosate® + Diuron® immediately after preparation, with Imazetapir® 2 hours after preparation, and Flumioxazine® 12 hours after preparation were not recommended due to the formation of sediments in the spraying tank due to changes in pH of the syrup.

Mendonça (2000) adds that in mixtures between herbicides, it is important to know the characteristics of the active molecules, in addition, the characteristics of solubility in water at 20 ºC, Know, Pka, and vapor pressure. As observed in our results, the more acidic pH positively influences the active molecules for most mixtures. This corroborates Costa et al. (2020) which I discussed about pH close to 6 where there is a greater amount of free cations that can bind to the active ingredients present in the mixture. When this occurs, precipitation and acceleration of product degradation are observed, consequently, a decrease in the available active ingredient and incompatibility of molecules in the mixture, which is particularly a serious problem for herbicides that require low pH, such as Glyphosate®. As described by Petter et al. (2012) acidic herbicides, when in solution with an acidic pH, show less dissociation, this is due to the predominance of charge neutrality. Wanamarta & Penner (1989) add that the acidification of the spray mixture reduces the dissociation of the molecules. Thus, herbicides dissolved in low pH conditions will be more easily absorbed by plants because the molecules are in an undissociated form.

Sediment formation is another serious problem between grout interactions. In some cases of incompatible mixtures, it is possible to verify the formation of these sediments, this is a natural phenomenon in liquids that are subjected to rest, requiring constant agitation of the syrup in the tanks before spraying, especially among combined treatments that present sedimentation soon after spraying. preparation. In our results, it was possible to verify that the interactions between the mixtures of the products Smart Zn®, Engeo®, Completo®, Plant Start®, Smart Cooper®, Bravonil®, Glifotal®, 2.4 D®, Smart Trio®, and B-Moly® resulted in the formation of sediments. For herbicides, the sedimentation process at the bottom of the spray tank results in less action on weed control, caused by the uneven concentration of the chemical active in the application (Petter et al., 2013), although this loss of action is not limited to only the class of herbicides, the others within the agricultural scenario. Lump formation was also reported in the study by Costa et al. (2020) where they verified the formation of lumps for individual use and in a mixture with Roundup Transorb® and the herbicides Promóleo® and Proof®. However, Roundup Transorb® used alone with water remained stable, regardless of whether or not it was shaken.

In addition to the formation of lumps, crystals can also form in syrups with incompatibilities or left to rest for a long period, this case was presented by Cunha & Martins (2022) where they found that the mixture between 2.4 D® + Clethodim® presented crystals immediately and after 2 h after Mixing. According to Kissmann (1998), crystals in the spray tank can clog filters and spray tips, as well as rupture hoses due to increased pressure and uneven application. In our results, no crystals and foam formation were observed, even in the study by Cunha & Martins (2022) all phytosanitary products after mixtures showed foam formation, for Imazetapir® and the mixtures with Diuron® + Flumioxazine®, Diurom® + Cletodim®, Imazetapir® + Cletodim®, Glyphosate® + Flumioxazine® and Glyphosate® + Cletodim® after 2 h of mixing. Foam formation is undesirable, Cunha & Alves (2009) add that the tank may overflow, reducing its capacity and there may also be a waste of chemical active ingredients.

Mixtures with different assets and share classes were also described by Rakes et al. (2017) who they found results similar to ours when herbicides + fungicides + insecticides were mixed in mixtures where they demonstrated suitability for using conjugates. Tank mixtures among herbicides Clincher® + Ricer®, Clincher® + Kifix®, Clincher® + Imazethapyr Plus Nortox®, Clincher® + Ricer® + Kifix®, Clincher® + Ricer® + Sirius® 250 CS, Imazethapyr Plus Nortox® + Basagran® 600, between herbicides and insecticides Clincher® + Ricer® + Arrivo® 200 EC, Clincher® + Kifix® + Arrivo® 200 EC, Clincher® + Imazethapyr Plus Nortox® + Arrivo® 200 EC, Clincher® + Ricer® + Kifix® + Arrivo® 200 EC, Clincher® + Ricer® + Sirius® 250 CS + Arrivo® 200 EC, Imazethapyr Plus Nortox® + Basagran® 600 + Arrivo® 200 EC, among fungicides Alterne® + Bim® 750 BR + Priori® 250 CS, and between fungicides and insecticides Bim® 750 BR + Actara® 250 WG, Alterne® + Bim® 750 BR + Priori® 250 CS + Actara® 250 WG, and Alterne® + Bim® 750 BR + Priori® 250 CS + Talisman® did not present any physicochemical change in the spray mix and are therefore compatible to be used in mixtures in the spray tank in plant treatments in rice crops. Moraes et al. (2019) found compatibility between the Deltamethrinae + Ghyphosate insecticide interaction in spray solution with consistent physicochemical parameters even after 24 hours of rest.

The fungicide mixtures showed that at pH 4.52 Zethamaxx® showed separation, at pH 4.22 there was harmonious interaction, and this is due to the pH and EC factors that also influenced the mixtures with pH 4.53 for Bravonil® products where it showed flocculation and at pH 4.11 there was harmonious interaction. For the fungicide class products Fox Xpro®, Evolution®, Fox Supra®, Vessarya®, and Abacus, the variation in the pH of the mixture did not influence the parameters evaluated as observed in our study.

Encouraging results were also obtained by Ribeiro et al. (2021) where they verified that the Fox® fungicide was compatible when mixed with several tested adjuvants. However, for the fungicides Orkestra® and Mancozeb Glory®, there was compatibility only at the moment after preparing the mixture, where break precipitates and lumps were observed at the bottom of the tank. As observed, pH close to neutrality tends to present a greater quantity of cations that bind to chemical active ingredients, forming precipitates also in fungicides, and this is not a phenomenon only observed in herbicides (Cunha; Alves, 2009; Petter et al., 2013). As for EC, our results for fungicides showed high values, which was also confirmed by Ribeiro et al. (2021) for fungicides in sprays for Fox®, Orkestra® and Mancozeb Glory® when associated with Prime® + Prime Citrus® adjuvants. According to Carlson & Burnside (1984) and Rheinheimer & Souza (2000), EC, when elevated, indicates the presence of large loads of ions, which can reduce the physiological effectiveness of the products. On the other hand, Maski & Durairaj (2010) report that EC is an important characteristic in electrostatic spraying.

For biological products from the biostimulant classes and foliar fertilizers + adjuvants in sprays, they demonstrated peaceful interactions without showing incompatibilities at alkaline pH 8. Andrade et al. (2018) verified compatibility between mixtures with Glyphosate® and biostimulants, forming a homogeneous and complete mixture where no incompatibility parameters such as sediments, lumps, crystals, and phase separation were observed; however, the pH of the solution was acidic, which positively influenced the mixture. Positive results are also discussed by Carvalho et al. (2011) where they verified harmonious compatibility between Nitrogen and Glyphosate® in syrup for desiccating *Sorghum halepense* and for the control of *Ipomoea triloba*. Promising results were obtained by Bessani et al. (2022) where they verified different doses of the herbicides 2.4 D® + Picloram® and foliar fertilizer where there was a synergistic effect on the control of *Vernonia polyanthes* weed in the recovery of pasture with *Panicum maximum*.

5. Conclusions

It is concluded that the majority of chemical active ingredients in different classes of action (herbicide, fungicide, insecticide, biostimulants, foliar fertilizers, and adjuvants) are suitable for producing complete and harmonic mixtures, however, there were some conflicts with the pH and conductivity parameters. electrical of the final syrup with the formation of sedimentation, separation, flocculation, and formation of lumps. The physicochemical compatibility between the classes evaluated here is dependent on the rest period, greater agitation, immediate application, concentration, and characteristics of molecules in an oily medium with phase formation in times greater than 10-30 min. Constant stirring before and during application can be a peaceful way to minimize the incompatibility observed in some products and also maintain control of the pH of the syrup.

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7. Authors' Contributions

Paulo Henrique Pessoa: experimental design, project and article writing, laboratory analysis, post-evaluation review, and publication. *Hemerson Alves Silva*: experimental design, project and article writing, laboratory analysis, post-evaluation review, and publication. *Letícia da Silva Lima*: laboratory analyses, preparation of grouts, analytical instrumentation. *Rafael Borges de Assis*: laboratory analyses, preparation of grouts, analytical instrumentation. *Nathan Alves Neres*: laboratory analyses, preparation of grouts, analytical instrumentation. *Jaqueline Chagas de Almeida*: laboratory analyses, preparation of grouts, analytical instrumentation. *Fernando Rodrigues Cabral Filho*: co-supervisor, final review of the study. *Christiano Lima Lobo de Andrade*: advisor, study review, publication.

8. Conflicts of Interest

No conflicts of interest.

9. Ethics Approval

Not applicable.

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