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Homeopathic preparations to increase resistance and development of yield in bean (*Phaseolus vulgaris*) crops

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Abstract

The common bean (*Phaseolus vulgaris*) is an essential part people's staple diet in Brazil as well as in some Latin American countries. The excessive use of agrochemical for pest and disease control negatively impacts human health, contaminates soil and water, harms biodiversity, and contributes to pest resistance. It is referred to a specific homeopathic preparation. In the context of homeopathy, the term "preparations" refers to homeopathic remedies that are created through a specific process of dilution and agitation. The use of highly diluted homeopathic preparations, which enhance the plants ability to resist diseases, represents a more sustainable and environmentally friendly alternative. In homeopathy, "Silicea" is used as a homeopathic remedy derived from silica which is not a silica in its natural form. The objective of this study was to evaluate the effect of *Silicea terra* and *Phosphorus* application in high dynamized dilutions, on morphometric and productive variables of common bean plants. Two experiments were carried out in a greenhouse and one experiment in the field, in a randomized block design for both situations. In greenhouse, the preparations were used in dynamizations 7, 12, 24, 36, 48 and 60CH (CH= Hahnemannian centesimal dilution order) and distilled water was used as control. In the field, the treatments were *Phosphorus* 48 and 60CH, *Silicea terra* 36 and 60CH, and distilled water as a control. In greenhouse, application of *Silicea terra* 36CH increased ($p< 0.05$) shoot dry biomass weight (9.78 g) and leaf dry biomass weight (5.36 g), compared to control. In the field, *Silicea terra* 36CH and *Phosphorus* 60CH increased bean productivity in relation to the control. The results indicate that homeopathic preparations had a high potential for improving development and consequently increasing yield when applied to common bean plants.

Keywords: high dilutions, homeopathy, biomass, dynamization, beans.
Abbreviations: CH_ hahnemannian centesimal dilution order; kg ha^{-1}_kilogram per hectare; g_grams; CV_coefficient of variation.

Introduction

Beans (*Phaseolus vulgaris*) are extremely important crops in Brazil from a socioeconomic perspective, since they are a source of income for many family farmers. Along with rice, they are part of Brazilians' staple diet, providing food and nutritional security for low-income populations (Souza et al., 2013). At a national level, the State of Santa Catarina stands out as a bean producer, with 105,000 tons per year and an average yield per hectare of 1770.00 kg ha^{-1} (Conab, 2020). Small family farmers are responsible for more than 70% of the state's production (Nita, 2017).

Crop management is mostly performed in a conventional manner, i.e., based on an intensive use of pesticides (Kluthcouski et al., 2009; Pignati et al., 2017). Such practice increases production costs, reduces biodiversity, and accumulates pesticide molecules in the environment through food chains (Santos and Pontes, 2013). Therefore, there is an urgent need to seek alternatives to these production models that demand more and more agrochemicals. On the other hand, the viability of these alternatives depends on offering reduced environmental impact with lower health risks, but also on ensuring a minimum income for rural family farmers (Vargas et al., 2012).

High dynamic dilutions (homeopathies) have been shown to have a high potential to support production systems without causing negative effects on the environment or leaving residues in food products (Teixeira and Carneiro, 2017). Mazón et al. (2020) found that bean plants treated with the homeopathic medicine *Natrum muriaticum* (Nat-m 7CH) contribute to the development of morphometric variables and a 50% increase in the photosynthetic rate in treated plants, compared to untreated plants. Pinheiro et al. (2019) reported that the use of *Arsenicum* 15 and 20CH (Hahnemannian

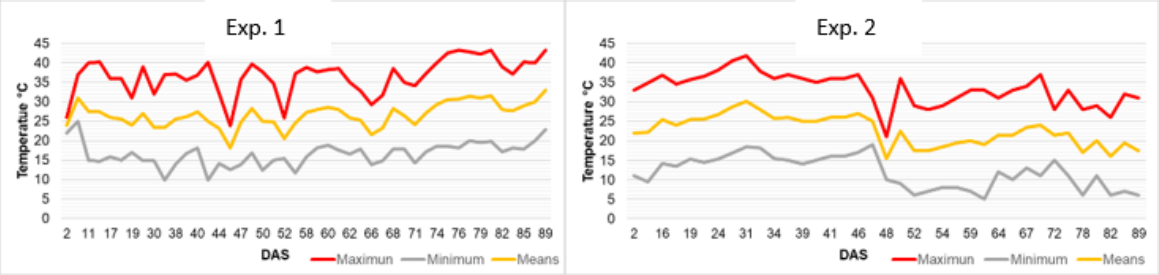

Fig 1. Temperature (°C) variation during the crop cycle in Exp.1 and Exp2. two. DAS: days after sowing.

Table 1. Dry biomass of leaves and stems of common bean cultivar SC204 predileto of the "preto" commercial group, submitted to homeopathic preparations in a greenhouse. Lages, SC, Brazil, 2020-2021.

	Leaves (g plant^{-1})		Stem (g plant^{-1})	
Preparations	Exp.1	Exp.2	Exp.1	Exp.2
Silicea terra 36CH	5.36 a	2.55^{ns}	4.43^{ns}	1.58^{ns}
Silicea terra 60CH	5.05 ab	2.08	4.05	1.03
Silicea terra 12CH	4.85 abc	1.69	3.85	0.88
Silicea terra 48CH	4.65 abc	1.98	4.07	1.32
Phosphorus 36CH	4.59 abc	1.77	3.73	1.10
Phosphorus 48CH	4.47 abc	1.82	3.32	1.08
Phosphorus 24CH	4.36 abcd	1.92	4.06	1.09
Silicea terra 7CH	4.33 abcd	2.15	3.71	1.45
Silicea terra 24CH	4.19 abcd	1.67	3.36	0.71
Phosphorus 12CH	4.15 abcd	1.89	3.19	1.25
Phosphorus 60CH	3.83 bcd	1.98	2.99	1.11
Distilled water	3.71 cd	1.50	3.45	1.07
Phosphorus 7CH	3.15 d	1.58	2.00	0.85
CV (%)	17.9	20.6	24.9	30.3

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability. ns= non-significant.

Centesimal Dilution Order) increased shoot growth of bean seedlings. Abasolo et al. (2020a) described that the homeopathic preparations *Silicea terra* 7CH and *Natrum muriaticum* 7CH significantly helped to improve the yield of *Brassica napus* L. by 46 and 44%, respectively, when compared to the control with distilled water. Also, Santos et al. (2011) reported that *Phosphorus* in 9CH dynamization has shown increases by 28% and 39% in growth and dry biomass yield for the *Verbena gratissima* plant in comparison to the control with distilled water. Oliveira et al. (2014) found that *Silicea terra* has the potential to elicit defense mechanisms by altering peroxidase, catalase, chitinase and phytoalexin activities. Therefore, such homeopathic preparation may constitute an excellent alternative for the control of pathogens in plants. Rissato et al. (2016; 2018) report that *C. carbonica* and *Phosphorus* have shown potential in reducing the intensity of *Sclerotinia sclerotiorum*.

Homeopathic preparations can easily be an excellent opportunity to help production models transitioning from conventional to agroecological ones (Andrade and Casali, 2011). However, the effectiveness of homeopathic preparations may be influenced by type of dynamization (Aparecida et al., 2020; Moreno, 2017).

Experiments are needed to evaluate different dynamizations of the same preparation, since different responses can be found depending on the dynamization being used (Bonato, 2007, Rissato et al., 2018). Contextualized studies on agricultural production facilitate the implementation of homeopathic therapy, which is consolidated among humans and is now a growing demand in agriculture (Boff et al., 2021).

The objective of this study was to evaluate the effect of homeopathic preparations in different dynamizations on the development of bean (*Phaseolus vulgaris*) crops and their response to yield. The present findings can provide useful data and; thus, support food production systems to achieve a substantial reduction in the use of agrochemicals in crops such as beans.

Results and Discussion

Effect of homeopathic preparations on the development of common beans

Homeopathic preparations differed from one another by the leaf dry biomass variable in experiment 1 (Table 1). Treatment with *Silicea terra* 36CH stimulated greater leaf development in bean plants, inducing increases of 2.2 and 1.6 g plant^{-1}

Table 2. Leaf and stem dry biomass of common bean cultivar SCS204 predileto of the "preto" commercial group, submitted to homeopathic preparations. Lages, SC, Brazil.

Preparations	Biomass (g plant^{-1})
Silicea terra 36CH	9.78 a
Silicea terra 60CH	8.50 ab
Silicea terra 48CH	8.45 ab
Silicea terra 7CH	8.18 abc
Phosphorus 24CH	8.08 abc
Phosphorus 36CH	8.05 abc
Silicea terra 12CH	7.45 bc
Phosphorus 48CH	7.44 bc
Phosphorus 12CH	7.16 bcd
Phosphorus 60CH	7.05 bcd
Silicea terra 24CH	6.97 bcd
Distilled water	6.48 cd
Phosphorus 7CH	5.41 d
CV *(%)*	20.0

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability.

compared to *Phosphorus* 7CH and distilled water. The same trend was not found in experiment 2, in which all homeopathic preparations produced the same outcomes as distilled water, both for leaf development and for stem biomass.

Silicea terra has been referred to as a potentiator of plant development. Abasolo et al. (2020b) found that *Silicea terra* 13CH increased leaf dry biomass (1.32g) and stem dry biomass (1.90g) in tomato seedlings, compared to treatment with water (1.15g and 0. 68g). In addition, the same treatment influenced the greater plant growth (6.6 cm) compared to the control treatment with distilled water (4.6 cm). Mazón and Suástegui et al. (2020) found a significant increase by 82% in the dry weight of bean plant leaves when plants were submitted to homeopathic preparations of *Magnesium metallicum* 31CH and *Magnesium-manganum phosphoricum* 3CH, compared to the distilled water control. Although no significant differences were found between treatments in experiment 2, *Silicea terra* 36CH stood out as having the highest values (Table 1). Non-significance between treatments can be attributed to the long periods of low temperatures (<25 °C) during the experiment (Fig 2). According to Barbano et al. (2001), the ideal average temperature for bean plants occurs in 25 °C. Thus, long periods of low temperatures during their vegetative growth may have nullified the action of homeopathies (Pereira et al., 2014).

Variance of the weight variable for total biomass in experiment 1 and experiment 2 showed homogeneity by Hartley's test (1950), allowing the performance of the combined analysis. The combined analysis showed that there were significant differences between the treatments, i.e., *Silicea terra* 36CH provided the highest development of total dry biomass (9.78 g), statistically differing from the control (6.48 g) but not from the *Silicea terra* treatments in the 60CH, 48CH and 7CH and *Phosphorus* in the 24CH and 36CH (Table 2).

In a study carried out by Pulido et al. (2014), it was found that the treatment with *Silicea terra* 30CH increased the dry weight of cabbage plants by 0.036 g compared to the treatment with *Carbo vegetabilis* 6CH (0.098 g plant^{-1}). Similar results were also found by Pulido et al. (2017) in broccoli seedlings: the homeopathic preparation of *Silicea terra* 30CH increased stem diameter, root length, and shoot and root dry mass of broccoli seedlings. Santos et al. (2011) reported that the treatment with *Phosphorus* led to an increase of 68% in the total dry mass of *Verbena gratissima* compared to control treatment with water.

It should be noted that shoot dry biomass of the plants was influenced by the treatments that induced higher leaf dry weight, e.g., *Silicea terra* 36CH (Table 2). It is known that leaf area and leaf dry weight are closely related (Guiscem et al., 2007). Therefore, plants with greater leaf area benefit from more photosynthetic activity, leading to greater allocation of plant biomass and stimulates the development of more vigorous plants with greater productive potential (Garcia-Bernal et al., 2020).

In general, increasing dynamization of homeopathic preparations did not progressively influence the response of the morphometry variables in common bean plants. According to Rissato et al. (2018), homeopathic preparations can act differently on plants according to the dynamization being used. In the present study, the homeopathic preparation *Silicea terra* in the 36CH dynamization had the best results in the development of the bean plant.

Effect of homeopathic preparations on common bean yield

No significant differences were found between treatments for the variables number of pods (NVA) and seeds per plant (Exp. 1 and 2). However, for the NVA variable, the homeopathic preparation *Silicea terra* 60CH presented the highest value (10.33) in experiment 1 and *Phosphorus* 36CH, the highest

Table 3. Yield of bean cultivar SCS204 predileto by the "preto" commercial group submitted to homeopathic preparations. Lages, SC, Brazil.

	Pods (No. plant)		Grain (No. plant)	
Preparations	Exp.1	Exp.2	Exp.1	Exp.2
Phosphorus 7CH	5.67^{ns}	2.75^{ns}	21.17^{ns}	10.73^{ns}
Phosphorus 12CH	8.42	3.42	31.92	13.94
Phosphorus 24CH	9.00	2.83	31.58	7.77
Phosphorus 36CH	7.67	4.17	24.42	13.83
Phosphorus 48CH	7.58	3.88	27.83	13.85
Phosphorus 60CH	8.00	3.58	30.08	11.74
Silicea terra 7CH	8.17	2.79	28.50	7.15
Silicea terra 12CH	8.92	1.83	32.17	6.50
Silicea terra 24CH	9.75	2.17	38.17	5.58
Silicea terra 36CH	8.92	3.58	32.00	11.75
Silicea terra 48CH	7.58	3.92	24.42	11.15
Silicea terra 60CH	10.33	3.25	38.42	10.50
Distilled water	6.17	2.63	21.33	5.23
CV (%)	22.4	37.0	31.0	50.0

*Means followed by the same letter, in the column, do not differ from each other by Tukey's test at 5% probability. ns= non-significant. Exp.1= Experiment 1 (10/14/2019-01/13/2020); Exp.2= Experiment 2 (02/15/2020-05/16/2020).

value (4.17) in experiment 2. The homeopathic preparations of *Silicea terra* 60CH, 24CH showed the highest number of seeds (38) in experiment 1 and *Phosphoru* 12CH, 36CH and 48CH, the highest number of seeds (13) in experiment 2 (Table 3).

Yield (kg ha^{-1}) and thousand seed weight (g), in the field, were significantly different between treatments (Table 4). *Silicea terra* 36CH and *Phosphorus* 60CH increased yield by 772 and 774 kg ha^{-1}, respectively, and thousand seed weight by 36 and 34.8 g, respectively, compared to the control, which was 2136.2 kg ha^{-1} and 196.19 g for a thousand seeds (Table 4). Field studies have shown the potential of homeopathy to increase the yield of different crops. Santos Junior et al. (2021) found that in a bean crop, application of *Silicea terra* resulted in 33% more yield (kg ha^{-1}) compared to the control (without application). In rice, Verdi et al. (2020) found 21% higher yield in treatments with homeopathic preparations of *Magnetitum* and *Arsenicum tartaricum* compared to untreated crops. Likewise, Freitas et al. (2015) found an increase between 10 and 15% in corn yield when treated with the homeopathic preparation *Ammonium carbinicum* 3 and 4CH, compared to the control with water.

Our findings indicate that treatments involving Silicea terra 60CH, Silicea terra 36CH, and Phosphorus 60CH surpassed the reference value when compared to the thousand seed weight of the SCS204 bean cultivar, as determined in this study. This reference value, set at 200g per thousand seeds, is endorsed by Epagri (2018) as an ideal benchmark.

Different works have shown that plants subjected to homeopathic preparations improve their internal processes and optimize their development to be more productive (Santos Junior et al., 2021; Pulido et al., 2014). Various research studies support the idea that highly diluted substances have a beneficial effect on plants. Specifically, these dilutions are believed to stimulate the plants' inherent defense mechanisms, balance subtle energies and rectify any imbalances, all of which contribute to fostering healthy growth. Additionally, these diluted substances are thought to have a positive impact on the metabolism of plants and their ability to adapt to challenging environmental conditions (Boff et al., 2020).

Materials and methods

Place and conducting the experiments

The study was carried out at the EPAGRI Experimental Station, Lages SC, from October 2019 to February 2021, in two stages. The first stage consisted of experiments in a greenhouse with homeopathic preparations of *Phosphorus* and *Silicea terra* in the dynamizations of 7, 12, 24, 36, 48 and 60CH (CH=Hahnemannian centesimal dilution order). The second stage, in the field, used the homeopathic preparations that showed the best response in the first stage and supported by bibliographical references, namely *Silicea terra* 36 and 60CH and *Phosphorus* 48 and 60CH. In both stages, the treatments used certified bean seeds (*Phaseolus vulgaris*) of the cultivar SCS204 Predileto from the "preto" commercial group.

The homeopathic preparations were obtained at the Laboratory of Homeopathy and Plant Health of EPAGRI, Lages, from matrices acquired at a reputable pharmacy registered for homeopathic compounding in Lages, SC. The homeopathic preparations were compsed in accordance with the methodology described in the Brazilian Homeopathic Pharmacopoeia (2011).

Experiment in greenhouse

In the first stage, two experiments were developed; the first (Exp. 1) between 10/14/2019 and 01/13/2020 and the second experiment (Exp. 2) between 02/15/2020 and 05/16/2020. The experiments were carried out in a greenhouse covered with transparent materials that allow sunlight to pass through for

Table 4. Grain yield (kg ha^{-1}) and thousand seed weight (g) submitted to homeopathic preparations.

Preparations	Yield (kg ha^{-1})	Thousand seed weight (g)
Silicea terra 36CH	2908.7 a	232.2 a
Phosphorus 60CH	2910.5 a	231.0 a
Phosphorus 48CH	2083.0 b	198.4 b
Silicea terra 60CH	2511.0 ab	224.6 ab
Distilled water	2136.2 b	196.1 b
CV (%)	13.5	6.0

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability. ns= non-significant.

plant growth and development of Seeds were sown in plastic pots with a capacity of 3.5 L of substrate. The substrate consisted of a mixture of black soil (90%), carbonized rice husks (5%) and vermiculite (5%). During the conduction of the experiments, the values for daily temperature, average maximum and average minimum temperature were, respectively, 36.43±4.85, 26.71±3.12, 16.17±3.28 °C in Experiment 1 (Exp.1) and 33.48±4.22, 22.73±3.78, 12.03±4.11 °C in Experiment 2 (Exp.2) (Fig 1).

Both experiments used a randomized block design with 13 treatments and four replications. The treatments consisted of homeopathic preparations of *Silicea terra* and *Phosphurus* - both in the dynamizations 7, 12, 24, 36, 48 and 60CH (CH=Hahnemanian centesimal dilution order) while distilled water was used as control treatment. The final dynamizations using homeopathic preparations were carried out in distilled water, dynamizing the total amount to be aplied (50 ml) per experiment unit.

The experimental units consisted of three bean plants (one plant per pot). The homeopathic preparations were applied weekly, starting at the appearance of the first trifoliate leaf (stage V3) until 65 days after sowing (DAS). The homeopathic preparations were applied on the soil surface, seeking to cover the area of the plant's root system in a volume of 50 ml of homeopathic preparation per experimental unit.

Both experiments were conducted in a double-blind system, i.e., neither the applicator nor the evaluator knew the identity of the treatments, which were only revealed after data processing.

When the plants reached the end of their cycle of 90 DAS, the following variables were evaluated in the three bean plants (experimental units): leaf dry weight, stem dry weight, and shoot dry weight (leaves and stem). To determine dry weight, the samples (leaf, stem) were placed in paper bags, taken to a drying oven at a temperature of 60 °C for 72 hours, and then weighed on a digital scale (model: AV8101P). The results were expressed in grams. The number of pods and seeds per plant were also evaluated.

Field experiment

The field experiment was carried out between 11/19/2020 and 02/20/2021. Homeopathic preparations were used with the dynamizations that presented the best responses in the morphometric variables in the experiments in the greenhouse. The treatments selected were the homeopathic preparations *Phosphorus* at 48CH and 60CH, *Silicea terra* at 36CH and 60CH and distilled water as a control. In conducting the experiment, manual weeding was carried out to control weeds and no fertilizers or any other agricultural inputs were applied. Soil preparation was carried out by plowing and harrowing and sowing with a manual planter.

The experiment used a randomized block design with four replications. The experimental units were composed of four lines of 4 meters in length and spaced at 0.5 meters, with the usable portion consisting of the two center rows delimiting an area of 2 m^2. The chemical analysis of the soil showed the following characteristics: pH 5.5; 3.8% MO; 35% clay; 7.76 cmolc/dm3 of Ca; 3.26 cmolc/dm3 of Mg; 51.0 mg/dm3 of P; 3.75 mg/dm3 Zn and; 12.7 mg/dm3 of Mn.

Application of the homeopathic preparations was targeted to the soil, every 15 days after sowing, following a proportion of 10ml per liter of water, using a knapsack sprayer with a capacity of 5L. In total, four applications were performed at fifteen-day intervals.

At harvest, the following variables were evaluated: grain yield (kg ha^{-1}) and thousand seed weight (TSW). The calculation of TSW was carried out by following the procedures of the Rules for Seed Analysis (BRASIL, 2009).

Statistical analysis

The data were subjected to analysis of variance (ANOVA), considering a significance level of 5%. The assumptions of normality and homoscedasticity were verified using the Shapiro-Wilk and Bartlett tests. Means were compared using Tukey's test at $p \leq 0.05$. The data were analyzed using the R environment (R Core Team, 2018).

Conclusion

The homeopathic preparations used in the present study have the potential to stimulate the vegetative development of beans (*Phaseolus vulgaris*). However, it was evident that the effect will depend on the dynamization. The best results were found with the homeopathic preparation *Silicea terra*, which provided plants with better development and yield in the field.

The present study showed that the use of homeopathic preparations is a viable alternative to obtain higher yields than those of the regional reference where the research was carried out. In addition, it can be included in the development of strategies for a sustainable management of common bean crops. Therefore, homeopathy demonstrates a high potential for use and is technologically feasible to replace agrochemicals in agriculture.

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