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Conyza bonariensis allelopathy on the germination and initial development of melons and cucumbers

Alelopatia de Conyza bonariensis na germinação e desenvolvimento inicial de melão e pepino

Tatiana de Campos Carrasco[1]*; Julia Nsa Asumu Oyana[2]; Fernando Teruhiko Hata[3]; Matheus Henrique Kendrick Coradassi[4]; Juliano Tadeu Vilela de Resende[5]

Highlights

Conyza bonariensis extract concentration determines stimulation or inhibition levels.
Low doses of *C. bonariensis* extract stimulate, and high doses inhibit seed performance.
Horseweed extract boosted germination but reduced seedling development.

Abstract

Melons and cucumbers are sensitive to the allelopathic effects of certain weeds, which can affect their germination, development, and productivity. Among these weeds, horseweed (*Conyza* sp.) stands out for its ability to interfere with several economically important crops, and is difficult to control because of its tolerance to glyphosate. Considering the importance of melon and cucumber production, and their competitive interactions with weeds, these crops require special attention from germination to harvest, mainly because of their susceptibility to competition. This study aimed to identify the effects of an aqueous extract of horseweed leaves (*Conyza bonariensis*) on seed germination and seedling development of melon and cucumber under laboratory and greenhouse conditions. The percentage of abnormal plants, seed germination rate, and biometric traits such as root and shoot lengths, seedling dry mass, and hypocotyl length were evaluated under different extract concentrations (1:5, 1:10, 1:15, and 1:20 v/v). The results indicated that horseweed extract increased both the germination percentage and growth of the root and shoot systems of melon seedlings in both environments. The findings demonstrated that both the environment (laboratory and greenhouse) and species influenced the response to the aqueous extract. The horseweed extract exhibited a variable effect: in some cases, it

[1] Master's Degree Student at Postgraduate Program in Agronomy, Universidade Estadual de Londrina, UEL, Londrina, PR, Brazil. E-mail: tatiana.carrasco@uel.br
[2] Undergraduate Student in Agronomy, UEL, Londrina, PR, Brazil. E-mail: julia.nsa.asumu.oyana@uel.br
[3] Prof. Dr., Department of Agronomy, Universidade Estadual de Maringá, UEM, Maringá, PR, Brazil. E-mail: fthata2@uem.br
[4] Undergraduate Student in Agronomy, UEL, Londrina, PR, Brazil. E-mail: matheuskendrickcoradassi@gmail.com
[5] Prof. Dr., Department of Agronomy, UEL, Londrina, PR, Brazil. E-mail: jvresende@uel.br
* Author for correspondence

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stimulated germination while reducing seedling growth, whereas in others, it reduced germination but stimulated growth. This variation is mainly attributed to environmental effects, genotypic differences, and their interactions. Furthermore, extract concentration played a significant role, as lower concentrations stimulated while higher concentrations inhibited the development of melon and cucumber seedlings.
Key words: Aqueous extract. *Cucumis melo. Cucumis sativus.* Horseweed. Weed.

Resumo

O meloeiro e pepineiro são sensíveis aos efeitos alelopáticos providos por certas plantas daninhas, podendo reduzir ou mesmo estimular a germinação, desenvolvimento e produtividade. Considerando a relevância da produção dessas culturas e suas relações de competição com plantas daninhas quando cultivadas em campo, o melão e o pepino demandam cuidados especiais, desde a germinação até a colheita, principalmente por sua fragilidade à competição. Objetivou-se identificar eventual interferência do extrato aquoso de folhas de buva (*Conyza bonariensis*), na germinação de sementes e no desenvolvimento de plântulas de melão e pepino em laboratório e casa de vegetação. Foram avaliados % de plantas com anomalias, % de sementes germinadas e caracteres biométricos como comprimento de raiz e parte aérea, massa seca das plântulas e comprimento de hipocótilo, sob diferentes concentrações do extrato (1:05, 1:10, 1:15 e 1:20). Os resultados indicaram que o extrato de buva aumentou a porcentagem de germinação e o crescimento do sistema radicular e aéreo das plantas de melão em ambos os ambientes. Os resultados evidenciam que tanto o ambiente (laboratório e casa de vegetação), quanto a espécie influenciaram a resposta ao extrato aquoso. O extrato de buva teve um efeito variável: em alguns casos, estimulou a germinação e reduziu o crescimento das plântulas, enquanto em outros reduziu a germinação e estimulou o crescimento. Essa variação se deve ao efeito do ambiente ou do genótipo ou da interação entre ambos. Além disso, a concentração do extrato também foi importante, pois concentrações menores estimularam, enquanto concentrações maiores inibiram o desenvolvimento das plântulas de melão e pepino.
Palavras-chave: Buva. *Cucumis melo. Cucumis sativus.* Extrato aquoso. Planta daninha.

Introduction

The family Cucurbitaceae has the largest number of species of economic interest among vegetable crops, with an emphasis on melon, watermelon, cucumber, and pumpkin. Cucumber (*Cucumis sativus* L.) is highly appreciated for its freshness when consumed fresh and for its peculiar flavor when consumed in pickled form. It can also be used in cosmetics and pharmaceuticals because of its nutraceutical properties. (Carvalho et al., 2013).

Melon (*Cucumis melo* L.) is a plant rich in minerals that can fully meet the requirements for vitamins A and C. It is also a valuable source of sugars, fibers, calcium, iodine, potassium, and phytochemicals, all of which generally possess preventive and anticancer properties. The ripe fruit is recognized for its medicinal properties, acting as a sedative, refreshing agent, alkalizer, mineralizing agent, antioxidant, diuretic, and laxative, among other benefits. Furthermore, it is the most widely exported vegetable crop in Brazil, particularly in Europe. (Landau et al., 2020).

When grown in the field, melons and cucumbers require special care from germination to harvest primarily because of their inability to compete with weeds. The use of mulch on beds mitigates competition and ensures crop production (Landau et al., 2020). However, when the crop is subjected to direct seeding, low seed germination and reduced growth and development are observed, affecting the final stand and crop uniformity (Nascimento et al., 2011).

With relatively small seeds compared to other cucurbits, it was initially assumed that the low germination rates of cucumbers and melons could be related only to physical soil factors or even water availability. However, research has demonstrated the allelopathic effects of weeds on melon seed germination, and even on histological and morphological abnormalities in newly emerged seedlings (Nakada et al., 2011). Verón et al. (2025) observed that although the aqueous extract of *Conyza* (horseweed) did not affect the germination or shoot development of melons, there were signs of root sensitivity, suggesting the action of secondary metabolites on the root system of the seedlings. With the decomposition of horseweed plants in cultivation areas, several substances are released into the soil, which may be responsible for germination and growth problems in cultivated plants.

Studies have reported that seed extracts of cumaru (*Amburana cearensis* (Allemao) A.C. Sm.) inhibits melon germination, and the leaf extracts of cumaru, juazeiro (*Zizyphus joazeiro* Mart.), and seed extracts of jucá (*Caesalpinia ferrea* Mart. ex Tul. var. ferrea*), which resulted in a higher percentage of abnormal melon seedlings. These abnormalities include absence of root hairs, necrotic and deformed roots, darkening and hardening of the root apex, and negative geotropism (Oliveira et al., 2020). When analyzing the allelopathic activity of aqueous leaf extracts of false boldo (*Plectranthus barbatus Andrews*) and rosemary (*Rosmarinus officinalis* L.), Dorneles et al. (2015) reported delayed germination and initial growth of melon plants.

In general, cucurbits are sensitive to the allelopathic effects of weeds, particularly during germination and early growth. The extract of the aerial part of Stryphnodendron adstringens increased the number of cucumber plants showing abnormalities (Barreiro et al., 2005). According to Deomedesse et al. (2019), the aqueous extracts of *Cyperus rotundus* tubers affect cucumber seed germination and vigor. The aqueous extract of *Hyptis suaveolens* (L.) Poit. has a moderate allelopathic effect on the germination of *Cucumis sativus* L. seeds (Saboia et al., 2018).

Among the main weeds, *Conyza* spp. (horseweed) affect economically important crops and are difficult to control because they are tolerant to glyphosate (Vargas et al., 2007). Horseweeds infest more than 40 crops worldwide (Holm et al., 1997). *C. canadensis,* at a density of 150 plants m^{-2}, reduced soybean yield by 83% under no-tillage conditions (Bruce & Kells, 1990). In sugar beets, *C. canadensis* reduced yield by 64% on a two-year average and inhibited the development of new shoots in grapevines by approximately 28% (Holm et al., 1997).

In addition to their competitive effects, allelochemicals present in plant-derived horseweed extracts may stimulate or inhibit germination and early growth of other species by inactivating or damaging metabolic growth pathways. These compounds can alter the fluidity of the phospholipid bilayer of cellular membranes, cause changes in photosynthetic and hormonal levels, and induce the accumulation of reactive oxygen species (Pereira et al., 2018).

The allelopathic activity of *C. canadensis* has been attributed to the presence of polyacetylenes, which are mainly exuded by the roots (Weaver, 2001). Aqueous horseweed extract reduced *Amaranthus viridis* germination by 90%. The highest extract concentration (0.6 g L^{-1}) caused greater inhibition of germination and germination speed index of *Digitaria insularis* and *Ipomoea triloba.* In contrast, less concentrated extracts may stimulate germination, growth, and plant development. Horseweed extracts contain hormones that, at low concentrations, can stimulate germination, such as gibberellic acid, which activates the synthesis of alpha-amylase and protease enzymes in the embryonic region and endosperm of seeds (Peralta et al.,2022).

Studies addressing the possible allelopathic effects of horseweed on the germination, growth, and development of cucumber and melon are scarce. Thus, the objective of the present study was to evaluate the effects of aqueous extracts of horseweed leaves on seed germination and the growth and development of melon and cucumber seedlings under laboratory and greenhouse conditions.

Materials and Methods

Assays with aqueous horseweed extract were conducted in two environments: laboratory and greenhouse.

For both environments, a completely randomized design was used, with five treatments and four replicates. The treatments consisted of different concentrations of horseweed aqueous extract (v/v) as follows: T1, distilled water; T2, 1:20; T3, 1:15; T4, 1:10; and T5, 1:05.

Fresh horseweed plants were collected before flowering to obtain extracts. Collection was performed on the same day that the experiments were conducted. The leaves were removed, separated, washed, and dried with paper towels to prepare the aqueous extract, following the methodology adapted from Pelegrini and Cruz-Silva (2012). Fresh horseweed leaves (160 g) were weighed and ground in a blender with 200 mL distilled water. The crude extract was then filtered through a qualitative filter paper. Aliquots of the filtrate were diluted with distilled water to obtain concentrations corresponding to the treatments used.

Cucumber seeds of the Verde Comprido cultivar and melon seeds of the cultivar Eldorado 300 were used.

For the laboratory assay, 100 seeds of each species were used per replicate, totaling 500 seeds per treatment. Seeds of each species were placed on germitest paper and stored in Gerbox containers. The aqueous extract corresponding to each treatment was sprayed onto the seeds in an amount equivalent to 20% of their weight, as established by the RAS (Rules for Seed

Analysis of the Ministry of Agriculture, Livestock, and Supply- BRAZIL, 2009). The Gerbox containers were placed in a growth chamber (BOD) at 25 °C, 85% relative humidity, and a 12-hour photoperiod. Every two days, the seeds were moistened with distilled water. After eight days, the germination percentage, root and shoot length, root and shoot dry mass, and percentage of seedlings with abnormalities were evaluated.

The greenhouse assay was carried out in 128-cell polystyrene trays filled with Tropstrato HT® substrate, composed of pine bark, peat, and vermiculite. The cucumber and melon seeds were sown at a depth of 1.0 cm. Fifty seeds were sown per replicate with 200 seeds per treatment. Before sowing, the trays were irrigated, and the seeds were treated with horseweed extract. The trays were kept in the greenhouse under an average temperature of 27 ± 3 °C and relative humidity of 80 ± 5%.

Seedling emergence was evaluated eight days after sowing. Seventeen days after sowing, the plants with intact roots were removed from the trays, washed under running water, and dried using paper towels. Abnormalities in the roots and shoots were evaluated, and measurements were taken for root and shoot lengths and total plant dry mass were measured. To obtain dry mass, the plants were placed in paper bags and kept in a forced-air circulation oven at 60 °C until constant weight was reached. The samples were weighed using an analytical precision balance (0.0001 g).

After meeting the assumptions of normality and homogeneity, the data were subjected to analysis of variance, and the results were evaluated by regression analysis using the Sirvar software (Ferreira, 2016). Means were grouped using the Scott-Knott test ($P < 0.05$). The fit of the equations was tested using the t-test ($p < 0.05$).

Results and Discussion

No melon or cucumber plants with abnormalities were observed in either of the assays, both in the laboratory and greenhouse. In the laboratory test, under fully controlled conditions, melon seeds treated with an aqueous extract of horseweed (*Conyza bonariensis*) showed a higher germination percentage than the control treatment (without application) (Figure 1A). The data fit a linear model, indicating that seed germination increased with the application of horseweed extract, regardless of the concentration used.

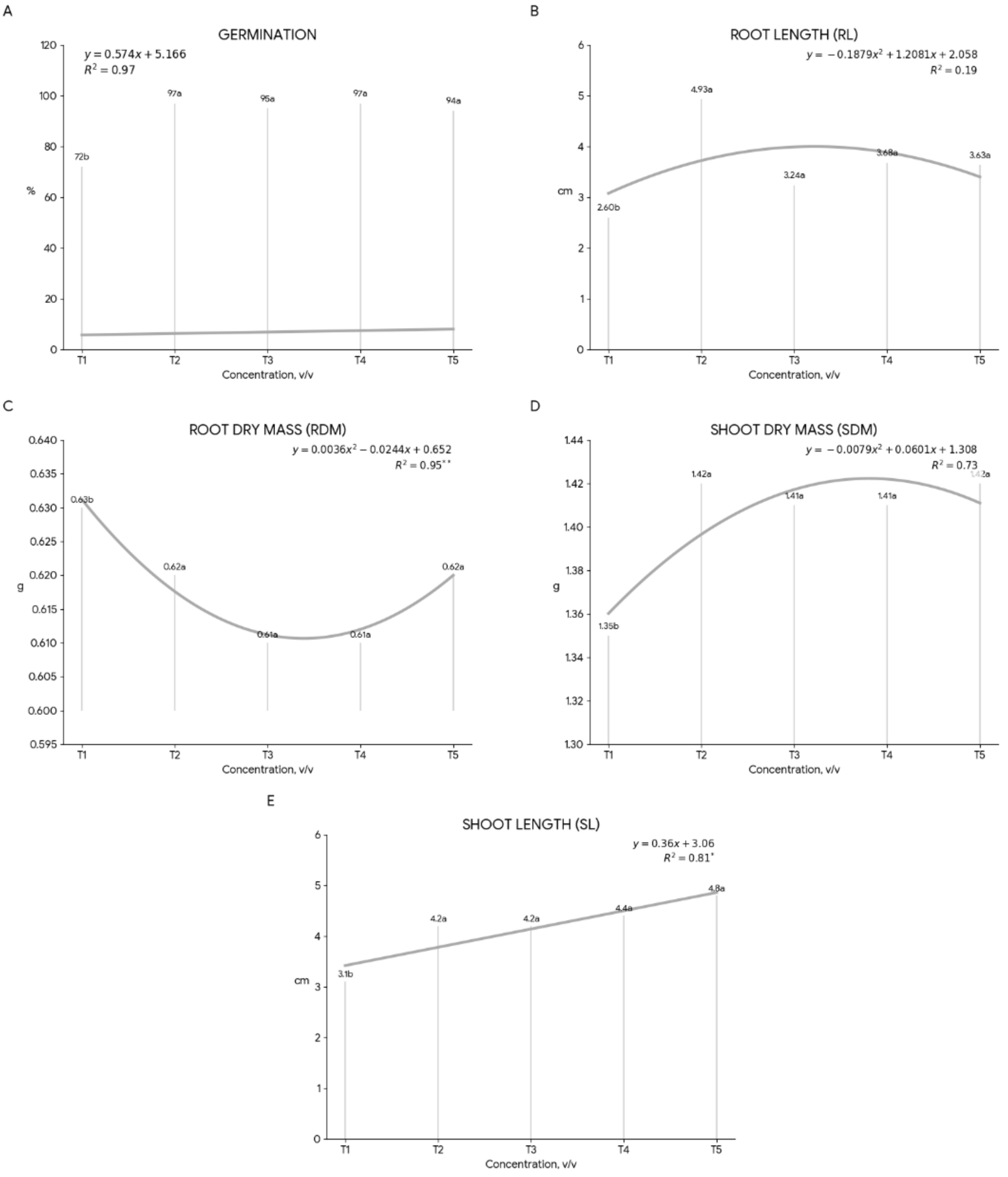

Figure 1. A – Germination (%), **B** – Root length (ROOT LEN – cm), **C** – Root dry mass (RDM – g), **D** – Shoot dry mass (SDM – g), and **E** – Shoot length (SL – cm) of **melon** seedlings treated with aqueous extract of *Conyza bonariensis* at different concentrations (v/v). T1 – distilled water; T2 – 1:20 v/v; T3 – 1:15 v/v; T4 – 1:10 v/v; T5 – 1:05 v/v, under **laboratory** conditions.
*Averages followed by the same letter do not differ according to Scott Knott mean grouping test (p<0.05).

Horseweed contains chemical compounds such as phenolic acids, flavonoids, limonene, steroids, cynarin, tannins, and coumarins, which may act in phytosanitary control or even stimulate the germination and early growth of other species (Macías et al., 2004). Hormonal and photosynthetic alterations, as well as the accumulation of reactive oxygen species, have been reported in the literature (Reigosa et al.,2006), which may explain the results observed.

Under stress conditions, plants tend to develop morphological, physiological, and biochemical responses through the production of various secondary metabolites. Metabolic alterations related to the modification of antioxidant enzyme activity such as catalase, superoxide dismutase, and ascorbate peroxidase in plants under the influence of allelochemicals represent an attempt to survive the new environmental condition and are associated with the plant's self-defense mechanism (Forman et al., 2010; Omezzine et al., 2014).

Costa et al. (2020), when using aqueous extract of horseweed to test allelopathy on soybean seeds, found no significant effect for germination percentage, demonstrating that the extract did not interfere with soybean seed germination.

Regarding the root length of melon seedlings, the aqueous extract of horseweed resulted in greater root length than the control, regardless of the extract concentration (Figure 1B). However, the laboratory results did not fit the applied regression model, which contradicted the results of the mean comparison test that indicated differences among treatments. Nevertheless, when evaluating hypocotyl length, which represents the shoot at this growth stage, a linear relationship was observed, where an increase in extract concentration promoted greater hypocotyl growth in melon seedlings (Figure 1E).

Based on these results, no allelopathic effect of the aqueous extract of horseweed was observed on the traits evaluated in the laboratory for melon plants, in contrast to reports in the literature. These results were surprising, as they indicated that the horseweed extract increased the germination percentage and growth of both the root system and shoots of melon plants. These results may have occurred because of the chemical components present in horseweed, mainly hormonal substances or precursors.

Horseweed contains several chemical compounds that are involved in the primary and secondary metabolism of higher plants, such as phenolic acids, flavonoids, essential oils, steroids, cynarins, tannins, and coumarins. According to Lehninger (2004), some of these compounds act directly or indirectly on hormone synthesis and serve as substrates for the formation of geranyl and geranyl pyrophosphate (GPP), precursors in the biosynthesis of gibberellic acid. Interestingly, the greater root length of melon seedlings did not result in greater dry mass accumulation, unlike that observed in the shoots, in which greater hypocotyl growth and dry mass accumulation were observed in the presence of horseweed extract. The root system is primarily responsible for water and nutrient absorption; therefore, its growth may occur because of cell turgor pressure caused by the presence of water. Thus, root length was associated with water content rather than dry mass accumulation, which explains the observed results.

It is well known that seed germination is stimulated by gibberellins, which activate the synthesis of enzymes that degrade endosperm reserves to produce simple sugars (Taiz & Zeiger, 2021), which explains the increased germination of melon seeds in our study.

Similarly, the greater root growth of seedlings treated with horseweed extract can be explained by the fact that phenolic acids and flavonoids may act in the auxin biosynthesis pathway, which is responsible for stimulating cell elongation and division (Taiz & Zeiger, 2021).

The assay, in which sowing was performed in trays maintained in a greenhouse, revealed germination stimulation in treatments with aqueous extract dilutions of 1:20 v/v and 1:15 v/v. The more concentrated treatments (1:10 v/v and 1:5 v/v) did not differ from the control, thus showing no alteration in the melon seed germination percentage (Figure 2A). Regression analysis, with moderate significance, indicated a quadratic adjustment of the data, showing that increasing the concentration of the aqueous extract did not necessarily result in increased melon seed germination.

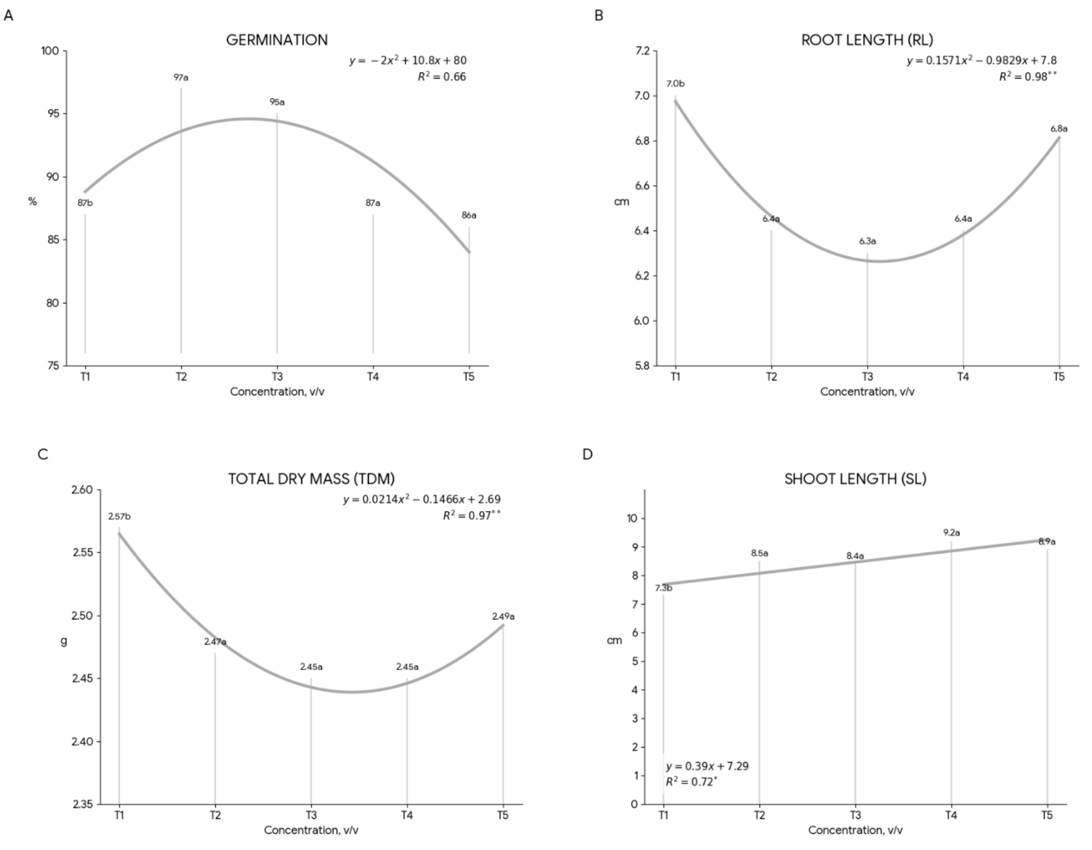

Figure 2. A- Germination (%), **B**- Root length (ROOT LENGTH - cm), **C**- Root dry mass (RDM – g), **D**- Shoot dry mass (SDM – g), of **melon** seedlings treated with aqueous extract of *Conyza bonariensis* at different concentrations (v/v). T1 – distilled water; T2 – 1:20 v/v; T3 – 1:15 v/v; T4 – 1:10 v/v; T5 – 1:05 v/v, sown in trays maintained under **greenhouse** conditions.
*Averages followed by the same letter do not differ according to Scott Knott mean grouping test (p<0.05).

Unlike the laboratory test results, the tray assay conducted in a greenhouse showed that the *Conyza* extract at lower concentrations was effective in increasing germination (Figure 2A), refuting the hypothesis of an allelopathic effect. These results demonstrate that phytohormones are the main agents responsible, as they respond to small environmental changes related to light, temperature, and humidity (Natarelli, 2019). This environmental change was sufficient for the different treatments to behave differently.

For root length, the data fit significantly to the quadratic model, indicating that the root length of melon seedlings was affected by the concentration of the aqueous Conyza extract (Figure 2B). This characteristic showed an allelopathic effect of the extract, in which the treated seedlings had shorter roots than those in the control treatment. The environmental interference in the melon's response to the *Conyza* extract is evident. In the laboratory, the extract did not show any allelopathic effect on root length (Figure 1B); instead, a synergistic effect was observed. However, in the tray cultivation under greenhouse conditions (Figure 2B), the same treatments clearly demonstrated allelopathic effects.

The aerial parts of the melon plants (Figure 2D) showed greater growth with an increase in extract concentration, fitting linearly. This result, as well as that in the laboratory (Figure 1E), contradicts the effects of *Conyza* extract on the different anatomical structures of melon plants. The results for root dry mass (Figure 2C) were consistent with those for root length (Figure 2B) but differed from those observed in the laboratory (Figures 1B and 1C). The dry mass of melon seedlings grown in trays under greenhouse conditions was higher in the control treatment, indicating that the *Conyza* extract interfered negatively regardless of the concentration (Figure 2C). The results for seedling dry mass were not compatible with those for hypocotyl length, in which more concentrated extracts promoted greater growth. As observed in the laboratory withroots, the greater growth of the melon hypocotyl may be related to the cell turgor pressure caused by water, which does not result in dry mass accumulation (Figures 1D and 1E).

Plant responses to the environment typically occur through hormonal stimuli. Thus, plant development occurs in a coordinated manner with programmed gene expression in the cell and is modulated by environmental signals, such as temperature, water availability, photoperiod, and light quality/intensity. These environmental signals are detected by specialized structures in plants, such as pigments and receptors, and are converted into chemical signals, namely plant hormones, inside the cells. These hormones, in turn, trigger secondary messengers that induce physiological responses in the cell nucleus (Nelson & Cox, 2022).

The results obtained in the greenhouse assay with germination in trays containing substrate allowed us to infer that the allelopathic effect of the *Conyza* extract occurred only for seedling dry mass and root length and that germination and shoot growth were stimulated by the aqueous *Conyza* extract.

Plant responses to environmental stimuli depend on minimal stimuli. Therefore, the concentration and balance between hormones as well as the presence and number of receptors for these hormones in target cells, are important elements for triggering a physiological response to be triggered. Any imbalance in the hormonal balance determines the modulation of plant growth and development, causing the effect to be either synergistic or inhibitory, whether in seeds or adults. Hormones regulate cell division, growth, and differentiation, as well as germination, and are able to promote or inhibit these processes (as in seed dormancy) (Miransari & Smith, 2014; Peleg & Blumwald, 2011; Shigenaga & Argueso, 2016).

The test was carried out with the cucumber crop in the laboratory to evaluate the allelopathic effects of the *Conyza* extract on germination, and initial development showed differences among the treatments. The data related to germination in the laboratory showed a quadratic fit for the regression analysis, indicating a concentration-dependent effect of the *Conyza* extract. Germination was lower in the presence of the extract when compared to the control treatment (Figure 3A), indicating an allelopathic effect. However, the germination percentages found, even under the extract treatment, were within acceptable parameters.

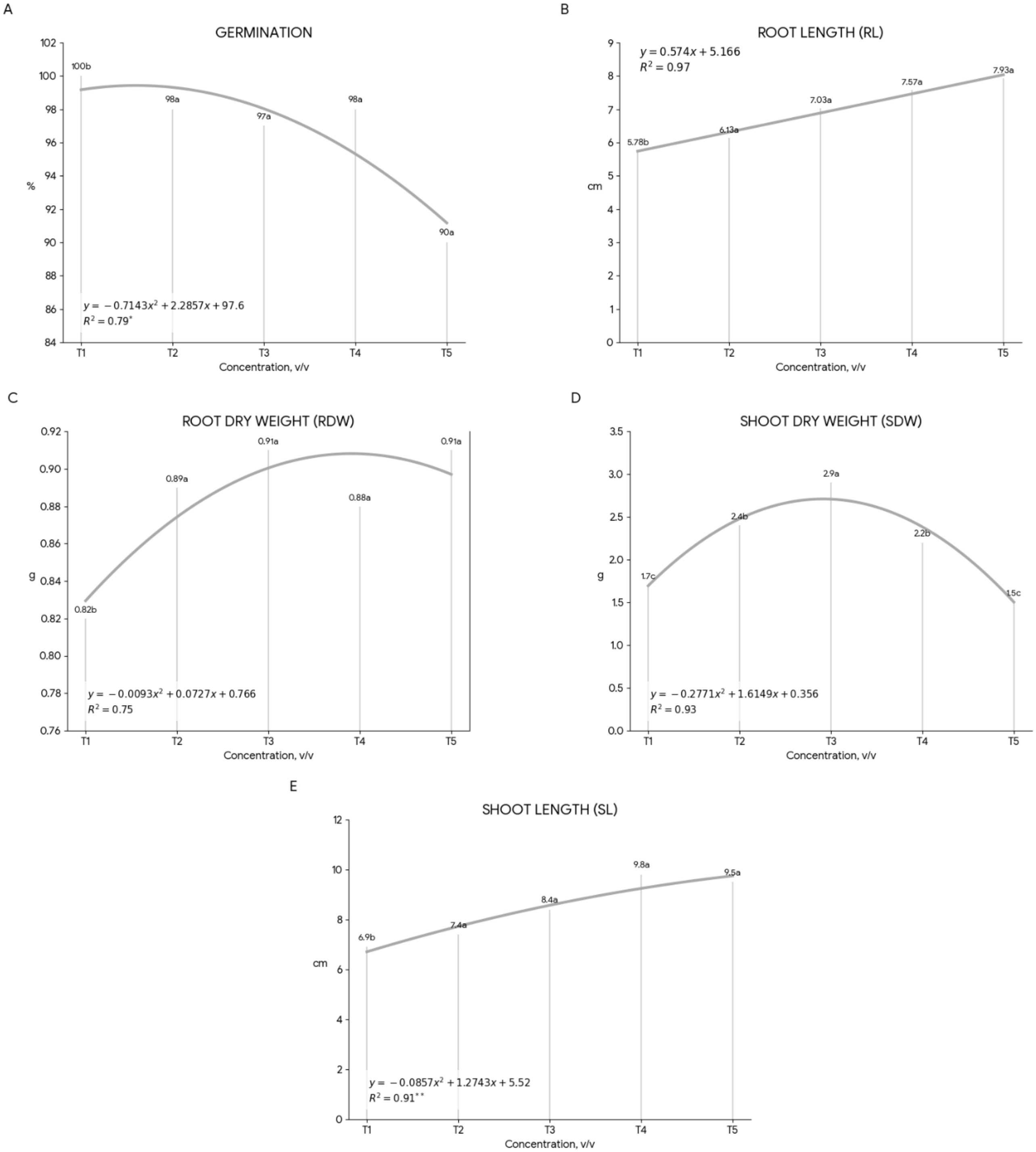

Figure 3. A – Germination (%), **B** – root length (ROOT LEN – cm), **C** – root dry mass (RDM – g), **D** – shoot dry mass (SDM – g), and **E** – shoot length (SL – cm) of **cucumber** seedlings treated with aqueous extract of *Conyza bonariensis* at different concentrations (v/v). T1 – distilled water; T2 – 1:20 v/v; T3 – 1:15 v/v; T4 – 1:10 v/v; T5 – 1:05 v/v, under **laboratory** conditions.
*Averages followed by the same letter do not differ according to Scott Knott mean grouping test ($p<0.05$).

When comparing two species of the Cucurbitaceae family (cucumber and melon) in a laboratory environment with controlled climatic factors, a divergent effect of the *Conyza* extract on seed germination was observed. This result shows that not only do climatic conditions interfere with the expression of the trait but also with the species. Genotype × environment interactions have been widely reported in the literature as a condition for the expression or non-expression of traits. In this study, it is evident that the synergistic or inhibitory effect of the *Conyza* extract depends not only on the environment and concentration, but also on the genetic background of the species and its interaction with the environment.

The data referring to root length evaluated in the laboratory for cucumber plants fit linearly, indicating that the increase in the concentration of the aqueous *Conyza* extract contributed to the increase in the root system length of cucumber (Figure 3B). An equivalent result was observed for melon crops with the same traits and environment. In this specific case, for root length, there was no species effect on trait expression. Treatments with *Conyza* extract resulted in a greater amount of dry mass in the roots, which differed from the control (Figure 3C). Regarding shoot dry mass accumulation in cucumber seedlings, the best result was obtained at the 1:15 v/v concentration, surpassing that of other treatments. The highest concentration of the extract (1:5 v/v) did not differ from the control, showing no synergistic or inhibitory interaction with dry mass accumulation.

The germination data of cucumber seeds in trays under greenhouse conditions showed a quadratic fit, indicating different responses depending on the concentration of *Conyza* extract applied (Figure 4A). The highest germination percentage was observed in the treatment with the 1:20 v/v concentration, demonstrating the synergistic effect of the *Conyza* extract. When more concentrated extracts (1:5, v/v) were used, a lower percentage of cucumber seed germination was observed, indicating an allelopathic effect. These results clearly show that *Conyza* extract can have either a synergistic or allelopathic effect on cucumber seed germination, with lower concentrations stimulating germination and higher concentrations inhibiting germination. The results obtained and the quadratic fit of the regression curve indicated a hormonal effect on trait variation.

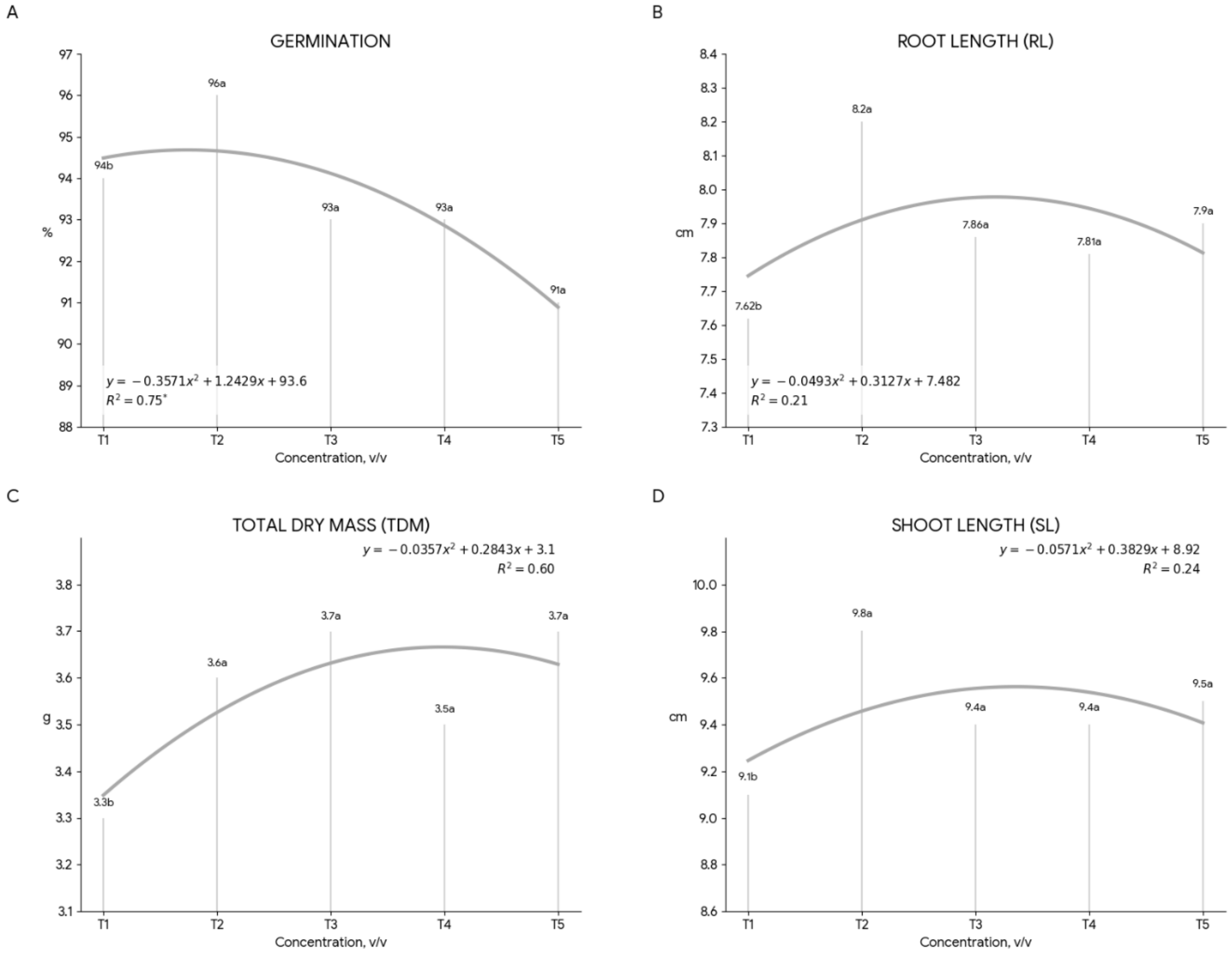

Figure 4. A – Germination (%), **B** – root length (ROOT LEN – cm), **C** – total dry mass (TDM – g), and **D** – shoot length (SL – cm) of *cucumber* seedlings treated with aqueous extract of *Conyza bonariensis* at different concentrations (v/v). T1 – distilled water; T2 – 1:20 v/v; T3 – 1:15 v/v; T4 – 1:10 v/v; T5 – 1:05 v/v, sown in trays maintained under **greenhouse** conditions.
*Averages followed by the same letter do not differ according to Scott Knott mean grouping test ($p<0.05$).

Although no significant fit was observed for the concentration of aqueous *Conyza* extract in cucumber plants under greenhouse conditions for root length, shoot length, and total seedling dry mass, the applied means test indicated variation. The extract concentration at a 1:20 v/v ratio resulted in greater root length, whereas the other concentrations did not differ from those of the control treatment (Figure 4B). These results allow us to infer the beneficial effects of *Conyza* extract when applied at low concentrations. Regarding hypocotyl length, the data did not fit the applied regression models; however, the less concentrated extract provided greater hypocotyl growth. The total dry mass accumulated in greater amounts when treatment with *Conyza* extract was applied (Figure 4C). Notably, the results allowed us to infer and presume the presence of hormones in the extract, which were the main agents responsible for the observed variations.

The substances found in *Conyza* promoted greater development of cucumber seedlings, probably because of the presence of hormones that act in cell elongation and division, especially auxins (Taiz & Zeiger, 2021). According to Silva et al. (2014), *Conyza* is a weed with high competitive potential, even in small quantities, which can directly affect the productivity of the main crop.

Considerations and Conclusions

In a laboratory environment, the aqueous extract stimulated melon seed germination, showing no allelopathic effects. Under the same environmental conditions, root growth was stimulated by the aqueous extract, although no dose-dependent effect was observed.

In greenhouse assays using seed trays, no allelopathic effects were detected on melon seed germination; however, a synergistic effect was observed at lower concentrations of the horseweed (*Conyza* spp.) extract, which promoted seed germination. Increasing the extract concentration enhanced the hypocotyl growth in melon seedlings. In contrast root growth and dry mass, were negatively affected by the aqueous extract, indicating an allelopathic effect likely influenced by environmental factors and the extract's chemical components, particularly its hormones.

In the laboratory, the aqueous extract exerted an allelopathic effect on cucumber seed germination, whereas the root length was positively affected (synergistic effect). The expression of a given trait can occur in response to genotype environment interactions. In the greenhouses, the lowest extract concentration (1:20 v/v) stimulated cucumber seed germination, whereas the highest concentration (1:5 v/v) resulted in allelopathic inhibition and reduced germination. Root growth increased at a 1:20 v/v concentration of horseweed extract, and seedling dry mass was enhanced by the extract, with the aerial dry mass being the highest at 1:15 v/v, outperforming the other treatments. Regarding hypocotyl length, the data did not fit the regression models; however, the lowest extract concentration promoted greater growth.

Based on these results, it was not possible to establish a single pattern of action for the horseweed extract nor to definitively classify its effect as synergistic or allelopathic on germination, dry mass, and root or shoot length in cucumber and melon. Nevertheless, interesting results were obtained, particularly concerning the influence of environment and species on the response to the aqueous extract. Surprisingly, horseweed extract stimulated germination while reducing seedling growth in some cases, or inhibited germination while stimulating growth in others. This inconsistency is primarily due to environmental and genotypic effects, or their interactions. Another relevant factor is the extract concentration, as lower concentrations tend to stimulate trait expression, whereas higher concentrations inhibit it.

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