

Effects of foliar extracts of guaba (*Inga edulis*) and cadaghi (*Corymbia torrelliana*) on coffee (*Coffea arabica* ‘Caturra Roja’) under nursery conditions in Chanchamayo, Peru

Efecto de extractos foliares de *Inga edulis* y *Corymbia torrelliana* sobre café (*Coffea arabica* ‘Caturra Roja’) en vivero (Chanchamayo, Perú)

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Abstract

The objective of this study was to determine the allelopathic effects of leaf extracts of the forest species guaba (*Inga edulis*) and cadaghi (*Corymbia torrelliana*) on coffee (*Coffea arabica* ‘Caturra Roja’) plants grown under nursery conditions in Chanchamayo, Peru. Different doses of fresh leaf extracts were applied to coffee plants using a completely randomized design, with four treatments for each forest species (T1 = 0%, T2 = 10%, T3 = 20%, and T4 = 30%) and 12 replicate plants per treatment. It was found that none of the foliar extracts had an allelopathic effect on coffee plants in terms of height, stem diameter, number of leaves and dry weight; however fresh weight was significantly altered following “cadaghi” treatment.

Key words: Allelopathy, forest species, coffee, plant extracts.

Resumen

Este trabajo se realizó con el objetivo de determinar el efecto alelopático en vivero de extractos foliares de guaba (*Inga edulis*) y cadagui (*Corymbia torrelliana*) sobre café (*Coffea arabica* “Caturra Roja”) en Chanchamayo (Perú). Se emplearon diferentes dosis de extractos de hojas frescas, bajo un Diseño Completamente al Azar con 4 tratamientos (T1=0, T2=10, T3=20 y T4=30%) y 12 repeticiones (1 planta=1 repetición). Se encontró que ninguno de los extractos foliares tuvo un efecto alelopático en las plantas de café en términos de altura, diámetro del tallo, número de hojas y peso seco, sin embargo para la variable peso fresco se encontró diferencias significativas en el tratamiento de “cadaghi”.

Palabras clave: Alelopatía, especies forestales, café, extractos vegetales.

Introduction

A well-designed agroforestry system can be both ecologically attractive and economically viable for farmers. However, the presence of trees can also have associated issues, such as competition for nutrients, light and water, increased evapotranspiration, and, in some cases, an increase in work (Benzing, 2001). Trees that are grown in association with coffee (*Coffea* spp.) plantations provide shade and reduce environmental stress for the crop but also modify the growing environment via their roots, branches, and leaves, which can have negative effects, such as the accumulation of toxic substances in the soil (allelopathy). Several studies have investigated the allelopathic potential of various plant species, such as forest trees (Ballester, Arias, Cobián, López & Vieitez, 1992; Da Silva, Bomfim, Almeida, & Borges, 2012; Sousa de Oliveira et al., 2005), fruit trees (Inoue et al., 2010), shrubs (Márquez &

Monteiro, 2001), forage (Souza, Rodrigues & Rodrigues, 1997), weeds (Goncalves, Tonet & Stofell, 2015; Rawat, Narwal, Kadiyan, Maikhuri, & Negi, 2012; Souza et al., 2011) and even cultivated plants such as rice (*Oryza* spp.) (Amb & Ahluwalia, 2016).

In Peru, coffee plantations occupy more than 420,000 ha, and nearly all of this cultivated land is in agroforestry systems or under shade trees. According to Julca et al. (2010), more than 48% of plantations use only trees in the genus *Inga*, 26% use *Inga* spp. mixed with other plant species, such as banana (*Musa* spp.), and the remaining 26% use a mixture of different forest species as shade, such as cedar (*Cedrus* spp.), mahogany (*Swietenia* spp.), and eucalypts (Eucalyptae).

Peruvian coffee farmers usually select the tree species they use based on the likely economic benefit they will obtain

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(wood, firewood, and/or fruit) and their availability in the production area. However, they do not have an adequate knowledge of the effects of the various tree species on the crop. For example, the allelopathic effect of some forest species on coffee has not been documented, despite the suspicion in recent years that this phenomenon is occurring in some coffee-producing areas of Peru, such as Tingo María and Chanchamayo, and is a reason for concern among coffee farmers – and this concern is even greater if one considers that the trees are used as permanent shade and the coffee plantations remain in the field for a long time. Therefore, the aim of this research was to investigate the allelopathic effects of the foliar extracts of guaba (*Inga edulis*) and cadaghi (*Corymbia torrelliana*) on the coffee (*Coffea arabica*) cultivar ‘Caturra Roja’ under nursery conditions in Chanchamayo, Peru.

Materials and methods

The trials were carried out in Annex 14 of the San Ramón District, Chanchamayo Province, Department of Junín, which is 850 meters above sea level.

Plant propagation.

Germination. Coffee (*C. arabica* ‘Caturra Roja’) seeds were disinfected with the fungicide Homai WP (2 g/100 seeds) and then broadcast outdoors at a density of 1 kg/m² in a germination bed that was 2 m long, 1 m wide, and approximately 25 cm high and contained washed, fine river sand as a substrate. After sowing, the seeds were covered with a thin layer of sand and the entire bed was covered with a jute blanket (which was later removed when the seedlings started to emerge). A 1.5-m-high shed was installed over the bed, which was constructed from wooden poles and had a raschel mesh roof. The seedlings remained in the bed until they reached the “butterfly state,” at which time they were transplanted into bags.

Seedling growth. Seedlings were grown in black polyethylene bags with a capacity of 1 kg containing farm soil that had been sterilized with hot water (80 °C for 1 h) to avoid the presence of phytopathogens. A hole was made in the center of each bag and one seedling was carefully placed in this, ensuring that the root was straight. The bags were then placed on a metal mesh table (3 m × 1 m) inside a 2.5-m-high shed built from wooden posts and with a raschel mesh roof that was covered with transparent plastic to maintain 40% shade and prevent the entry of rain.

Irrigation. A watering can was used for irrigation, and an attempt was made to always maintain the substrate at field capacity. Due to the climatic conditions during the development of the trial, irrigation was carried out every other day throughout the experimental period.

Pest and disease control. The coffee leaf miner *Leucoptera*

coffeella and the pathogenic fungus *Cercospora coffeicola* were not controlled during the trial to avoid any interference with the results of the study.

Weed control. Manual weed control was performed continuously throughout the trial to avoid any issues with weed invasion.

Preparation of plant extracts. Extracts were obtained from the fresh leaves of two forest species that are used as shade in coffee plantations by farmers in different coffee-growing regions in Peru (Table 1).

Table 1. Forest species used in the trials

| Scientific name | Family | Common name | Code |
|-----------------------------|-----------|--------------|------|
| <i>Inga edulis</i> | Fabaceae | Guaba, pacae | EVie |
| <i>Corymbia torrelliana</i> | Myrtaceae | Cadaghi | EVet |

To obtain the plant extracts, leaves were taken from the middle third of the crown of each tree species and processed following the methodology of [Cazón, De Viana, and Gianello \(2000\)](#). Briefly, the leaf material (50 g) was air dried at room temperature and ground, following which 400 ml of distilled water was added and the mixture was left for 12 h. Then, 100 ml of distilled water and 250 ml of methyl alcohol (sufficient volumes to reach a final ratio of 1:5:10 of plant tissue:methanol:water) were added and left to macerate at room temperature for 48 h. The resulting hydroalcoholic solution was filtered and concentrated in a rotary vacuum evaporator to reduce the initial volume to approximately 250 ml, from which aliquots were taken for use in the assays. This procedure was carried out in the Q6 Laboratory of the Department of Chemistry of the Faculty of Sciences of the National Agrarian University – La Molina (UNALM), Peru. The extracts were added to the irrigation water (250 ml/bag) and applied to the coffee plants at a range of concentrations at 30 and 60 days after transplant (dat).

Experimental design. The study involved two trials (one trial per forest species), each of which had a completely randomized design with four treatments and 12 replicates per treatment, where each replicate corresponded to a single plant/bag. The details of the treatments are presented in Table 2. Duncan test ($\alpha=0.05$) was used to analyze the data.

Table 2. Dosages used to determine the effect of each foliar extract on *Coffea arabica* ‘Caturra Roja’.

| Treatment | Plant extract concentration | Amount (ml) |
|-----------|-----------------------------|-------------|
| T1 | Control | 0.0 |
| T2 | 10% | 2.5 |
| T3 | 20% | 5.0 |
| T4 | 30% | 7.5 |

Plant measurements. The following measurements were made on each coffee plant:

- Plant height (cm) from the base of the plant to the apex of the terminal bud at 0, 30, 60, 90, and 120 dat.
- Stem diameter (mm) 2 cm from the base of the plant at 0, 30, 60, 90, and 120 dat.
- Number of real and fully developed leaves at 0, 30, 60, 90, and 120 dat.
- Fresh weight (g) of the total plant (aerial part and roots) at the end of the trial.
- Dry weight (g) of the total plant at the end of the trial, which was determined by kiln drying the materials at 60 °C for 72 h.

Results

Plant height. There were no significant differences (Duncan test, $\alpha=0.05$) in the heights of the coffee plants between the treatments in which the foliar extracts were applied and the control treatment for either of the forest species evaluated. In the guaba trial, the greatest height was reached with the control treatment (T1; 16.38 cm), followed by T3, T4, and T2. In the cadaghi trial, the greatest height was reached with the control treatment and

T3 (17.21 cm), followed by T2 and T4. Thus, none of the treatments had a negative effect on the longitudinal growth of the plants, with the height increasing over time in all cases (Figure 1).

Stem diameter. There were no significant differences (Duncan test, $\alpha=0.05$) in the stem diameters of the coffee plants between the treatments in which foliar extracts were applied and the control for either of the forest species evaluated. In the guaba trial, the largest diameter corresponded to the control, followed by T2, T4 and T3, whereas in the cadaghi trial, the largest value corresponded to T2, followed by T1 = T4 and T3. Thus, none of the treatments had a negative effect on the diametral growth of the plants, with the diameter increasing with time in all cases (Figure 1).

Number of leaves. There were no significant differences (Duncan test, $\alpha=0.05$) in the numbers of leaves on the coffee plants between the treatments in which the foliar extracts were applied and the control treatment for either of the forest species evaluated. In the guaba trial, the highest number of leaves corresponded to T2, followed by T3, T1, and T4, whereas in the cadaghi trial, the highest value corresponded to T2, followed by T1, T3, and T4. Thus, none of the treatments had a negative effect on the rate of leaf production, with the number of leaves increasing over time in all cases (Figure 2).

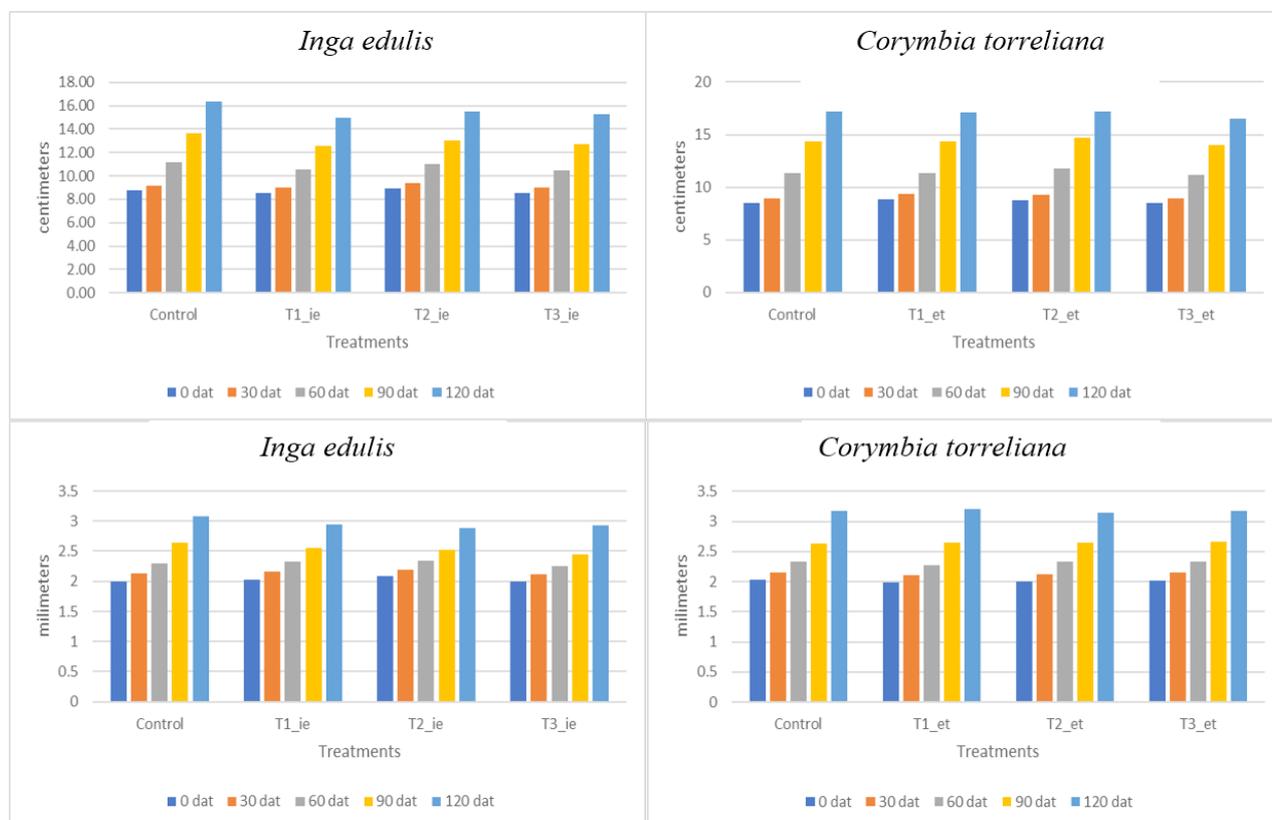


Figure 1. Heights (cm) and diameters (mm) of coffee (*Coffea arabica* 'Caturra Roja') plants treated with foliar extracts of guaba (*Inga edulis*) and cadaghi (*Corymbia torrelliana*) under nursery conditions in Chanchamayo, Peru. dat, days after transplant. See Table 2 for a description of the treatments.9

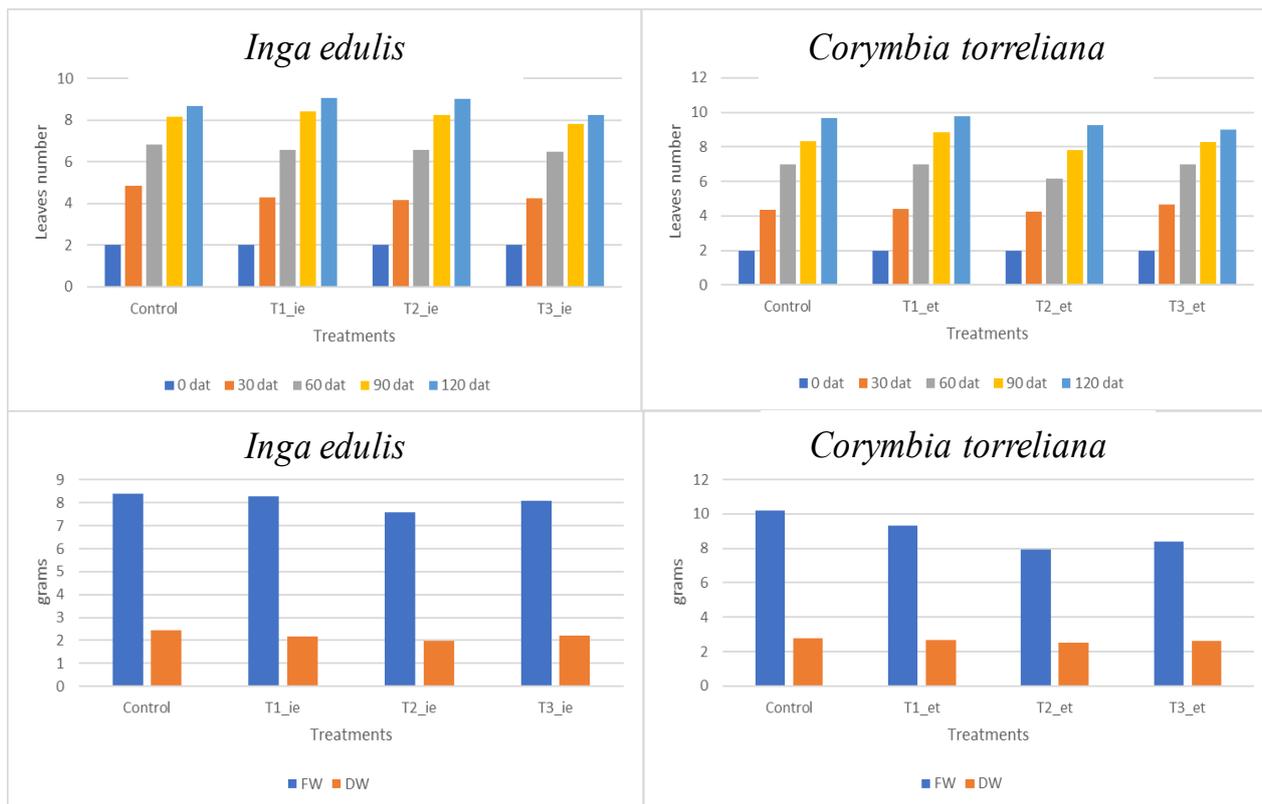


Figure 2. Numbers of leaves and fresh and dry weights (g) of coffee (*Coffea arabica* ‘Caturra Roja’) plants treated with foliar extracts of guaba (*Inga edulis*) and cadaghi (*Corymbia torrelliana*) under nursery conditions in Chanchamayo, Peru. dat, days after transplant; FW, fresh weight; DW, dry weight. See Table 2 for a description of the treatments.

Fresh and dry weights. There was a significant difference (Duncan test, $\alpha = 0.05$) in the fresh weights of coffee plants between treatments in the cadaghi test, with the control plants having a significantly greater weight than those in the T2, T3, and T4 treatment groups. However, there were no significant differences between the treatments in terms of dry and fresh weight (Figure 2).

Discussion

Cadaghi is recommended for use in agroforestry systems with a wide range of crops (Grisi, Anair Souto, Passos da Silva, Venturim, & Nogueira, 2011), while guaba is the preferred shade species in coffee plantations (Villagaray & Bautista, 2011). However, there have been no previous studies on the allelopathic effects of either of these forest species on cultivated plants. In the present study, the leaf extracts from these species had no significant allelopathic effects on coffee plants under nursery conditions, which contrasts with the findings of several other studies on closely related forest species. For example, Benzing (2001) reported that eucalyptus (*Eucalyptus* spp.) have negative allelopathic effects on many other plant species via their roots and leaves. However, it has also been shown that the allelopathic potential of eucalyptus can be more pronounced in areas with low and erratic rainfall due to a lack of dilution of the phytotoxic substances excreted

by these trees, with *E. camaldulensis* appearing to have a particularly high allelopathic potential, resulting in it not being recommended for use in mixed plantations under low and/or erratic rainfall conditions (May & Ash, 1990; Lisanewok & Michelsen, 1993; as cited by Cecccon & Martínez-Ramos, 1999).

In terms of other forest species, Singh et al. (1998), as cited by Benzing (2001) found a very clear negative relationship between the distance from poplar (*Populus deltoides*) trees, the phenol content in the soil, and wheat (*Triticum aestivum*) yield. In addition, the aqueous leaf litter extract of *Alnus nepalensis* produces allelopathic effects on the germination percentage of species such as wheat, millet (*Eleusine coracana*), mustard (*Brassica nigra*), and pea (*Pisum sativum*) (Uniyal & Chhetri, 2010, as cited by Varela, 2017) these effects on both the germination and root growth of pea were confirmed, as well as on the root growth of rice (*Oryza sativa*) and beans (*Phaseolus vulgaris*) (Kumar et al. , 2006, as cited by Varela, 2017). Furthermore, Lines and Fournier (1979) concluded that both aqueous extracts and essential oils of the vegetative and reproductive parts of cypress (*Cupressus lusitanica*) have an allelopathic effect on the germination of the herbaceous species *Lepidium costaricensis*, *Bidens pilosa*, and *Rumex crispus* under laboratory conditions.

Souto, Gonzales and Reigosa (1993) examined how the phytotoxicity produced by the aerial parts of four forest

species, eucalyptus (*Eucalyptus globulus*), acacia (*Acacia melanoxylon*), oak (*Quercus robur*), and pine (*Pinus radiata*), changed during the decomposition process in four different soils by measuring the effects of soil extracts on the germination and growth of lettuce (*Lactuca sativa*) seeds under laboratory conditions. Their results indicated that allelopathic effects may occur during the decomposition of residues from the four forest species, with eucalyptus and acacia having the largest effects and oak and pine having more moderate effects. Pérez et al. (2011) investigated the allelopathic potential of the leaves of three exotic tree species (*Alianthus altissima*, *Robinia pseudoacacia*, and *Ulmus punila*) and one autochthonous species (*Populus alba*) in Henares, Spain on the germination of four native herbaceous understory species (*Chenopodium album*, *Dactylis glomerata*, *Brachypodium phoenicoides*, and *Brachypodium silvaticum*) under laboratory conditions, and reported that leaf litter extracts from all of the tree species tended to reduce the speed and, to a lesser extent, the germination rate of the four herbaceous species, with no consistent effect of leaf extracts from exotic trees on native herbaceous plants. In a study on the retardant effects of fresh eucalyptus (*Eucalyptus robusta*) leaf extract on the growth of bean, corn (*Zea mays*), lettuce, pea, rice, and sorghum (*Sorghum vulgare*) seeds under laboratory conditions in Pereira, Colombia, Ávila et al. (2007) observed that the extract had a greater effect on the monocotyledons (corn, rice, and sorghum) than on the dicotyledons (peas, beans, and lettuce), indicating that this could form a basis for the development of grass control products.

The results of the present study indicated that any allelopathic substances that are present in the plant extracts obtained from the two forest species investigated would not accumulate at the concentrations required to cause an effect (be it positive or negative) on coffee plants under nursery conditions. However, it has been shown that allelopathic activity depends on several factors, such as the sensitivity of the receptor species, release of the toxin to the environment, biotic and abiotic activity, and factors that interact with the toxin in the soil (microorganisms, temperature, pH, etc.) (Blum et al., 1992, cited by Blanco, 2006). Therefore, it is also possible that the environmental conditions and test time were not optimal for observing the activities of these substances.

Conclusions

The foliar extracts of guaba and cadaghi did not have any allelopathic effects on the coffee cultivar 'Caturra Roja' under nursery conditions in Chanchamayo, Peru.

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