



Impact of aromatic plants on olive trees production

Matheus Batista dos Santos Pepe¹, Kevin Fontana Fantinatti¹, Camila de Toledo Castanho^{*1}

¹Universidade Federal de São Paulo (UNIFESP), Departamento de Ciências Ambientais, 09913-030, Diadema, São Paulo, Brazil

*Corresponding author: ctcastanho@unifesp.br

ABSTRACT

Plants interact in positive ways, facilitating each other. We can use this facilitative effect in agriculture by intercropping crop plants with aromatic plants that provide benefits such as the repulsion of pests, resulting in a reduction of agrochemical inputs and higher crop productivity. Considering this potential benefit, we conducted a study in an olive grove to test the effect of the aromatic plants basil (*Ocimum basilicum*) and rosemary (*Salvia rosmarinus*) on olive (*Olea europaea*) production. We planted six aromatic saplings under olive trees (20 trees with basil and 20 with rosemary) and selected 20 olive trees with no aromatic plants as a control group. To estimate the productivity of olive trees, we measured the number of inflorescences per tree, the number of fruits, and the average fruit weight. After nine months, we did not find a significant difference in the productivity of olive trees intercropped with aromatic plants compared to olives without the association. However, basil and rosemary had low mortality rates and showed substantial growth. Consequently, while probably not increasing olive production, the absence of negative effects on olive productivity indicates that intercropping aromatic plants and olives is viable and might provide diversification and economic resilience to small farmers.

Keywords: basil (*Ocimum basilicum*); facilitation; olive (*Olea europaea*); plant-plant interaction; rosemary (*Salvia rosmarinus*)

Introduction

Plant-plant interactions are fundamental to defining the structure and organization of plant communities. Competition happens when plants compete against each other for resources, decreasing the performance of evolved plants (Brooker *et al.*, 2007). However, plants can also increase the performance of neighboring plants by improving environmental conditions and/or resource availability through an interaction called facilitation (Brooker *et al.*, 2007). There are many mechanisms through which facilitation can occur. Beneficial plants can ameliorate the conditions that reduce other plants' performance by providing shade from excessive light, increasing water availability through hydraulic lift (Horton & Hard, 1998),

increasing nitrogen content in the soil (Stern 1993; Bonanomi *et al.*, 2011; Pappa *et al.*, 2012) and even repelling herbivores through aromatic compounds (Tang *et al.*, 2013; Zhang *et al.*, 2017; Song & Han 2020). Although most facilitative interactions have been identified in natural ecosystems (Callaway & Walker 1997), these positive interactions between plants have also been explored in managed environments, such as areas under restoration (Gómez-Ruiz *et al.*, 2013) and agricultural areas (Brooker *et al.*, 2015a).

Facilitative interactions between plants can bring many benefits to human-altered environments. Historically, intercropping was and still is used in many societies to boost farmland production of food (Ngapo *et al.*, 2021; Moore *et al.*, 2022). More recently, it has also been

Received May 12, 2023; Accepted July 22, 2024

Editor-in-Chief: Thaís Elias Almeida; Associate Editor: Vanessa Rezende

How to cite:

Pepe MBS, Fantinatti KF, Castanho CT. 2024. Impact of aromatic plants on olive trees production. *Acta Botanica Brasilica* 38: e20230082. doi: 10.1590/1677-941X-ABB-2023-0082



suggested that intercropping can be a viable alternative to the use of agrochemicals when facilitative species are included, allowing for more sustainable production of food in crop fields and ecosystem services (Brooker *et al.*, 2015b; Mthembu *et al.*, 2019; Pierre *et al.*, 2022). This is especially true considering the use of inorganic fertilizers and pesticides has been on the rise since the start of the Green Revolution (Smith, 1972) and delivers notable risks to human health and the degradation of the environment (Tilman *et al.*, 2002; Nicolopoulou-Stamati *et al.*, 2016).

Basil (*Ocimum basilicum* L.) and rosemary (*Salvia rosmarinus* Spenn.) are aromatic species from the Lamiaceae family, which are known to produce volatile chemicals capable of repelling insects (Werker 1993; Schader *et al.*, 2005; Zhang *et al.*, 2014; Song *et al.*, 2015; Issa *et al.*, 2017; Li *et al.*, 2021). Studies have shown the benefits of intercropping aromatic herbs with several crops, such as coffee, tomato, pepper, cotton, apple, tea and pear (Schader *et al.*, 2005; Bustos *et al.*, 2008; Carvalho *et al.*, 2009; Song *et al.*, 2015; Zhang *et al.*, 2017; Li *et al.*, 2021; Zhang *et al.*, 2021), but little is known about their effect on olive groves, a traditional Mediterranean crop whose cultivation has growing in Brazil in the last century (Villa & Oliveira 2012). There is evidence of benefits towards soil quality and olive productivity when associated with legumes and cereals (Panozzo *et al.*, 2020; Beniaich *et al.*, 2020; Ozturkmen *et al.*, 2020), but there is still no knowledge of olive and aromatic herbs intercropping. The objective of this study was to test if basil and rosemary improve the yield of olive trees (*Olea europaea* L.). We expected to find a higher number of flowers and a higher number and weight of fruits produced by olive trees intercropped with aromatic plants compared with a conventional olive crop without associated species. Additionally, we tested if the location of the aromatic plants around the olive tree (six different distances from the olive stem) influences the performance of associated aromatic plants.

Material And Methods

Experimental design

We conducted the experiment in an olive grove (Fig. 1) in the city of Aiuruoca, MG, southeastern Brazil (21° 58' 32" S, 44° 36' 10" W). The mean annual precipitation in Aiuruoca is 1,603 mm, most of it concentrated between October and March (Pinto *et al.*, 2014). The climate is described as dry-winter humid subtropical according to the Köppen climate classification (Beck *et al.*, 2018).

The olive trees of the Alberquina variety (exsiccata deposited at São Paulo Federal University Herbarium - HUFSP - under voucher n° 2348) were planted in 2012 and 2013 with an equidistant spacing of around 4 x 6 meters. We selected 60 non-neighbouring, similar-sized trees with a minimum distance of one tree between them (i.e., ~8m) to minimize interference among samples. Sample trees also were located at a minimum distance of 10 m from the edge of the olive grove to minimize possible edge effects. The treatments were orderly arranged across samples so that the first sample tree was associated with rosemary, the next one without associated aromatic (thus serving as control), and the third one was associated with basil. This sequence was repeated until all 60 sample trees had been assigned to one treatment.

In May 2018, we clear-cut the area beneath the canopy of all 60 sample trees removing all grassy vegetation. Next, we planted six saplings of rosemary (Fig. 2A) and six saplings of basil (Fig. 2B) beneath each of the 20 sample trees, according to their treatment. Exsiccates of both aromatic species were deposited at São Paulo Federal University Herbarium - HUFSP - under voucher n° 2349 for rosemary (*Salvia rosmarinus* Spenn.) and voucher n° 2350 for basil (*Ocimum basilicum* L.). Samplings of aromatic plants were used instead of seeds to guarantee a certain volume of aromatic biomass immediately after transplantation and the start of the experiment. Furthermore, the aromatic



Figure 1. Study area, Aiuruoca, MG. (A) General view of the olive grove from the farmhouse. (B) View from inside olive grove.



Figure 2. Intercropping between aromatic plants and olive trees. (A) Rosemary intercropped with olive trees. (B) Basil intercropped with olive trees.

plants were transplanted under the canopy of the olive trees instead of between the tree lines to increase the proximity between the consociated plants and also to not disturb the olive grove management, which includes the use of agricultural vehicles between the tree lines. Twenty olive trees remained without aromatic plants to serve as control. To test the performance of aromatic plants under different conditions of shade, saplings were planted at six different distances near the olive stem (Fig. 3). We irrigated the area around all trees for the following month in case there was no rain and clipped the grasses monthly to avoid competition with the aromatic plants.

Olive trees performance

We estimated the productivity of olive trees by measuring the number of inflorescences, the number of fruits, and the average fruit weight per tree. We divided the crown of each tree into three different heights and four different quarters each. For each tree, we then randomly chose one quarter at each height to be sampled (i.e., three samples per tree). Each sample consisted of the number of inflorescences (in September 2018) and fruits (in February 2019) inside a volume of 0.027m^3 (i.e., a cube with 30 cm side length). To estimate the number of inflorescences/fruits for the entire tree we first estimated the total crown volume (TCV) of each tree using an adapted Eq. (1) based on Sola-Guirado *et al.* (2017):

$$TCV = \frac{1}{6} \pi \times D_1 \times D_2 \times (H_t - H_s) \quad (1)$$

where D_1 and D_2 are the two perpendicular crown diameters in meters, H_t is the total tree height in meters and H_s is the height to crown base, in meters. D_1 and D_2

were estimated with a measuring tape by evaluating the plant crown on two horizontal and perpendicular lines (north-south; east-west). H_t and H_s were estimated using a bamboo stick marked every half meter. With the mean number of inflorescences/fruits per sample and the TCV, we were able to estimate the total inflorescence and fruit count for each tree using the following equation (Eq. 2):

$$\text{Total inflorescences OR fruits} = \frac{TCV \times \text{tree average} \frac{\text{inflorescences}}{\text{fruits}}}{0.027\text{m}^3} \quad (2)$$

We also measured the mean weight of the tree's fruits. One fruit was randomly picked from each of the sample heights at each tree, totaling three fruits per tree. Some trees had no fruit production that year and therefore could not be sampled. We dried the fruits in an oven at a constant 55°C until they had a constant weight. They were subsequently weighed on an electronic analytical balance. Following that, we averaged the fruit's dry weight for each tree.

We also evaluated aromatic plants' growth. We measured the height and diameter at ground level (DGL) of each plant at the start (May 2018) as well as at the end (February 2019) of the experiment. DGL was measured with a measuring tape and then converted into the basal area using the following equation 3:

$$\text{Basal area} = \pi \left(\frac{DGL}{2} \right)^2 \quad (3)$$

where DGL is the diameter of the stem at ground level. If the individual plant had more than one stem, all the stems on the ground had their individual basal area calculated. After that, we summed all the stems' basal areas for the estimation of the basal area of the entire plant. We then calculated the differences between the height and basal area at the start and end of the experiment for each plant.



Data analysis

To guarantee all samplings of olive trees under distinct intercropping treatments have similar sizes, we performed an ANOVA (with $\alpha=0.05$), where the independent variable was the treatment (control, rosemary or basil) and the dependent variables were the height and basal area at the ground level of the olive trees. To test for differences in mean productivity among treatments, we also used ANOVA. In this case, the independent variable was the treatment (control, basil or rosemary) and the dependent variables were the mean number of inflorescences, the mean number of fruits (both estimated for each olive tree), and the mean fruit weight per tree. Finally, to test for the influence of the olive position on the growth of rosemary and basil, we performed an ANOVA of each aromatic species and growth metric. The independent variable was the position of each aromatic seedling (six levels), and the dependent variables were the difference between the aromatic seedlings' height and basal area at the start and end of the experiment. We used the R environment (R Development Core Team, 2021) for all statistical analyses.

Results

As expected, before the beginning of the experiment all sample trees were similar in height ($F_{57,2}=0.66$; $p=0.52$), DGL ($F_{57,2}=0.21$; $p=0.81$) and canopy volume ($F_{57,2}=0.86$; $p=0.43$). Furthermore, intercropping with aromatic plants did not impact olive trees' productivity. There was no significant difference in the mean number of inflorescences ($F_{57,2}=0.67$; $p=0.51$, Fig. 4A), the mean number of fruits ($F_{19,2}=0.17$;

$p=0.84$, Fig. 4B) or the mean weight of fruits ($F_{45,2}=0.58$; $p=0.56$, Fig. 4C) between olives with aromatic plants and control. However, the lack of influence of aromatic plants on olive trees cannot be attributed to the poor establishment of aromatic plants since both aromatic plants had low mortality rates (20% for rosemary and 6% for basil) and showed substantial growth during the nine months of the experiment, independent of the position around the olive tree (Table 1). Basil plants were, on average, 4.1 times larger in basal area ($t=11.3$; $n=113$; $p<0.0001$) and 141% taller compared to the beginning of the experiment ($t=25.7$; $n=113$; $p<0.0001$). Similarly, rosemary plants at the end of the experiment were 3.6 times larger in basal area ($t=12.4$; $n=96$; $p<0.0001$) and 133% taller ($t=23.2$; $n=96$; $p<0.0001$).

Discussion

We did not find a significant increase or decrease in olive productivity when intercropped with aromatic plants compared to the control, which suggests aromatic plants do not facilitate or compete with olive trees. On the other hand, after nine months, aromatic plants had higher survivorship and growth nearby olive trees.

Even though it has been demonstrated that aromatic plants can repel insects in plantations of pepper, cotton, apple, and tea (Schader *et al.*, 2005; Zhang *et al.*, 2014; Song *et al.*, 2015; Issa *et al.*, 2017; Li *et al.*, 2021) the beneficial effect should only be detected when the predation of the herbivorous insects is relevant and negatively impact the main crop. Thus, if herbivory by insects was low or absent, a possible positive effect of the aromatic plants would be low as well. Although the low rates of predation are the more likely scenario here, further tests are necessary to

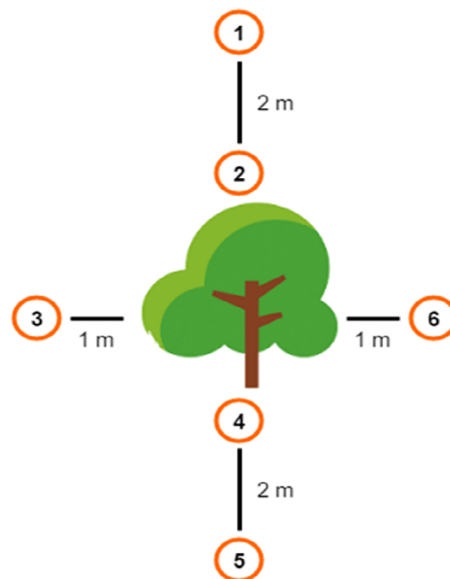


Figure 3. Arrangement of aromatic plants and their positions in relation to the olive tree. The numbers inside the circles represent the position of each plant.

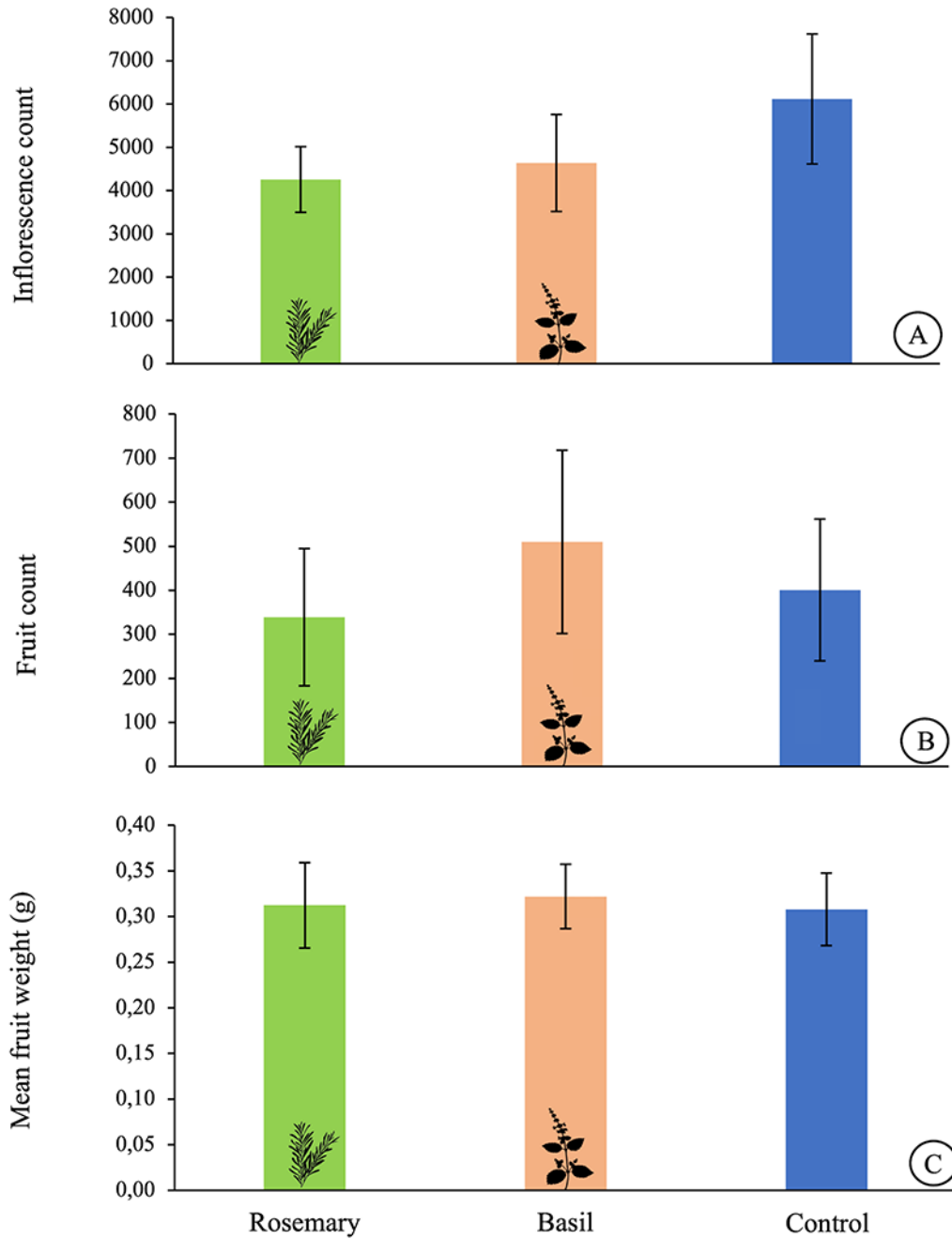


Figure 4. Mean and standard error of olives' productivity (per tree) under each intercropping treatment. A) number of inflorescences (sample size = 20); B) number of fruits (*sample size = 7, 8, 7) and C) mean fruit weight (*sample size= 15,17,16). *Sample size numbers are rosemary, basil and control respectively.

Table 1. Summary results related to the effect of position (see Fig. 3) around olive trees on the growth of aromatic plants after nine months of experiment. DF= degree of freedom for the numerator and denominator.

		Mean $\pm$ SE	DF	F-statistic	P-value
Rosemary	Δ Height (cm)	46.3 $\pm$ 19.6	90,5	0.82	0.54
	Δ Basal area (mm ²)	39.2 $\pm$ 31.1	90,5	1.17	0.33
Basil	Δ Height (cm)	46.2 $\pm$ 19.1	107,5	1.32	0.26
	Δ Basal area (mm ²)	68.5 $\pm$ 64.4	107,5	2.08	0.07



provide information on the effect of the density and age of aromatic plants on insect repulsion. Since the accumulation of essential oils of these aromatic plants is correlated positively to the number of leaves and flowers (Payne 1978; Werker 1993), higher densities and/or increased duration of the experiment (and thereby plant growth) might have an impact on productivity. The size, age, and density of aromatic plants during the flowering and fructification stages of olive trees could then be crucial to potentialize intercropping positive effects under moderate to high herbivore pressure.

Although the absence of facilitation is an unexpected result, the absence of competition between the intercropped species is promising. This result indicates there is a small niche overlap between the involved species, which might be due to differences in root depths among olives and aromatic plants (Masmoudi-Charfi *et al.*, 2011; Nishida 2011), resulting in low competition for water or nutrients. Then, while intercropping small aromatic plants with olive trees may not provide positive effects on the olive tree's productivity, it does not appear to impair their performance either. On the other hand, both aromatic species had high survival and similar growth in different positions around the olive trees. These results indicate that the shade of an olive tree does not prevent a good performance of aromatic plants. Therefore, since the aromatic plants produce valuable crops and essential oils of basil and rosemary are used in a variety of applications for food, medicine and cosmetics products (Borges *et al.*, 2019; González-Minero *et al.*, 2020; Dhama *et al.*, 2021), intercropping might be a valuable method to improve overall farm productivity and crop diversity.

The low overall productivity might have played a role in the lack of detection of the overall effect of intercropping on the olive trees' productivity. The reasons for the inconsistency are largely unknown, but the decrease might be due in part to alternate bearing, as it has been shown that olive trees have alternate periods of low and high growth and fructification (Rodrigues & Correia 2009; Kour *et al.*, 2018). Low winter temperatures are also important for olive flowering (Martin 1990), and the particular climatic condition of that year could explain the noticeable drop in olive productivity in this study, as there was a pronounced increase in mean temperature in the coldest months of 2018, during the olive trees' flowering (World Weather Online 2021). As human activities worldwide begin to have an increasingly notable effect on the climate of the planet (IPCC 2021), plant-plant interactions are also expected to change (Souza *et al.*, 2021). Thus, it is important to consider the abrupt abiotic human-caused changes in environments if we are to correctly evaluate how different plants can interact with each other in the future.

Intercropping aromatic plants around olive trees shows great potential for increasing species richness in olive groves without any negative effects on olive trees. This approach can provide more options for production and contribute to

economic stability in this type of farm system. As human activities influence an ever more unstable climate (IPCC 2021), agricultural systems are bound to be impacted by these changes (Nelson *et al.*, 2009). Intercropping with aromatic plants or other valuable intercrops can offer higher species diversity and improve financial security in Brazilian olive farms.

Acknowledgments

We thank Nélío Weiss for providing permission for the experiments on his farm and providing financial support. We thank Leda Montero Lorenzo and Thomas Püttker for their suggestion during the experiment planning. We thank Alexandre Adalardo de Oliveira for permitting us to use his laboratory at USP. We thank Alexandre and Thomas for suggestions in an earlier version of the manuscript. We acknowledge the National Council for Scientific and Technological Development (CNPq) for a PIBIC scholarship provided to MBSP.

Authors' Contribution

Camila T. Castanho was responsible for the study conception and design, project administration, and funding acquisition. The three authors collected data. Matheus B.S. Pepe and Camila T. Castanho performed data analysis. The three authors wrote and edited the manuscript.

Conflict Of Interest

We declare no conflicts of interest in carrying out the research and publishing the manuscript.

References

- Beniaich A, Silva MLN, Guimarães D *et al.*, 2020. Assessment of soil erosion in olive orchards (*Olea europaea* L.) under cover crops management systems in the tropical region of Brazil. *Revista Brasileira de Ciência do Solo* 44: e0190088.
- Borges RS, Ortiz BLS, Pereira ACM, Keita H, Carvalho JCT. 2019. *Rosmarinus officinalis* essential oil: A review of its phytochemistry, anti-inflammatory activity, and mechanisms of action involved. *Journal of Ethnopharmacology* 229: 29-45.
- Bonanomi G, Incerti G, Mazzoleni S. 2011. Assessing occurrence, specificity, and mechanisms of plant facilitation in terrestrial ecosystems. *Plant Ecology* 212: 1777-1790.
- Bustos AP, Pohlen HAJ, Schulz M. 2008. Interaction between coffee (*Coffea arabica* L.) and intercropped herbs under field conditions in the Sierra Norte of Puebla, Mexico. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 109: 85-93.
- Brooker RW, Maestre FT, Callaway RM *et al.*, 2007. Facilitation in plant communities: The past, the present, and the future. *Journal of Ecology* 96: 18-34.
- Brooker RW, Karley AJ, Newton AC, Pakeman RJ, Schöb C. 2015a. Facilitation and sustainable agriculture: A mechanistic approach to reconciling crop production and conservation. *Functional Ecology* 30: 98-107.

- Brooker RW, Bennett AE, Cong WF *et al.*, 2015b. Improving intercropping: A synthesis of research in agronomy, plant physiology and ecology. *New Phytologist* 206: 107-117.
- Callaway RM, Walker LR. 1997. Competition and Facilitation: A Synthetic Approach to Interactions in Plant Communities. *Ecology* 78: 1958-1965.
- Carvalho LM, Nunes MUC, Oliveira IR, Leal MLS. 2009. Produtividade do tomateiro em cultivo solteiro e consorciado com espécies aromáticas e medicinais. *Horticultura Brasileira* 27: 458-464.
- Dhama K, Sharun K, Gugjoo MG *et al.*, 2021. A Comprehensive Review on Chemical Profile and Pharmacological Activities of *Ocimum basilicum*. *Food Reviews Internationa* 39: 119-147.
- Gómez-Ruiz PA, Lindig-Cisneros R, Vargas-Rios O. 2013. Facilitation among plants: A strategy for the ecological restoration of the high-Andean forest (Bogotá, D.C. – Colombia). *Ecological Engineering* 57: 267-275.
- González-Minero FJ, Bravo-Díaz L, Ayala-Gómez A. 2020. *Rosmarinus officinalis* L. (Rosemary): An ancient plant with uses in personal healthcare and cosmetics. *Cosmetics* 7: 1-17.
- Horton JL, Hard SC. 1998. Hydraulic lift: A potentially important ecosystem process. *Trends in Ecology and Evolution* 13: 232-235.
- IPCC. 2021. Summary for Policymakers. In: MassonDelmotte V, Zhai P, Pirani A *et al.* (eds.). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, Cambridge University Press.
- Issa RB, Gautier H, Gomez L. 2017. Influence of neighbouring companion plants on the performance of aphid populations on sweet pepper plants under greenhouse conditions. *Agricultural and Forest Entomology* 19: 181-191.
- Kour D, Bakshi P, Wali VK, Sharma N, Sharma A, Iqbal M. 2018. Alternate Bearing in Olive - A Review. *International Journal of Current Microbiology and Applied Sciences* 7: 2281-2297.
- Li X, Lu X, Zhang Z *et al.*, 2021. Intercropping rosemary (*Rosmarinus officinalis*) with sweet pepper (*Capsicum annuum*) reduces major pest population densities without impacting natural enemy populations. *Insects* 12: 74.
- Martin GC. 1990. Olive flower and fruit population dynamics. *Acta Horticulturae* 286: 141-154.
- Masmoudi-Charfi C, Masmoudi M, Ben Mechlia N. 2011. Root distribution in young Chétoui olive trees (*Olea europaea* L.) and agronomic applications. *Advances in Horticultural Science* 25: 112-122.
- Moore VM, Schlautman B, Fei SZ *et al.*, 2022. Plant Breeding for Intercropping in Temperate Field Crop Systems: A Review. *Frontiers in Plant Science* 13: 843065.
- Mthembu BE, Everson TM, Everson CS. 2019. Intercropping for enhancement and provisioning of ecosystem services in smallholder, rural farming systems in KwaZulu-Natal Province, South Africa: a review. *Journal of Crop Improvement* 33: 145-176.
- Ngapo TM, Bilodeau P, Arcand Y *et al.*, 2021. Historical Indigenous Food Preparation Using Produce of the Three Sisters Intercropping System. *Foods* 10: 524.
- Nelson GC, Rosegrant MW, Koo J *et al.*, 2009. Climate change: Impact on Agriculture and Costs of Adaptation. Washington D.C., International Food Policy Research Institute.
- Nicolopoulou-Stamati P, Maipas S, Kotampasi C, Stamatis P, Hens L. 2016. Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture. *Frontiers in Public Health* 4: 148.
- Nishida F. 2011. Vegetable Root Depth - To Gauge Watering Depth. <https://celosangeles.ucanr.edu/files/121762.pdf>. 23 Sept. 2021.
- Ozturkmen AR, Ramazanoglu E, Almaca A, Çakmakli M. 2020. Effect of intercropping on soil physical and chemical properties in an olive orchard. *Applied Ecology and Environmental Research* 18: 7783-7793.
- Panozzo A, Bernazeau B, Desclaux D. 2020. Durum wheat in organic olive orchard: Good deal for the farmers? *Agroforestry Systems* 94: 707-717.
- Pappa VA, Rees RM, Walker RL, Baddeley JA, Watson CA. 2012. Legumes intercropped with spring barley contribute to increased biomass production and carry-over effects. *Journal of Agricultural Science* 150: 584-594.
- Payne WW. 1978. A Glossary of Plant Hair Terminology. *Brittonia* 30: 239-255.
- Pierre JF, Latournerie-Moreno L, Garruña-Hernández R *et al.*, 2022. Maize legume intercropping systems in Southern Mexico: A review of benefits and challenges. *Ciência Rural* 52: e20210409.
- R Core Team. 2021. R: A language and environment for statistical computing. <https://www.R-project.org/>. 2 Apr. 2023.
- Rodrigues MA, Correia CM. 2009. O ciclo bienal da oliveira. In: Rodrigues MA, Correia CM (eds.). *Manual da safra e contra safra do olival*. Bragança, Instituto Politécnico de Bragança. p. 17-21.
- Schader C, Zaller JG, Köpke U. 2005. Cotton-basil intercropping: Effects on pests, yields and economical parameters in an organic field in Fayoum, Egypt. *Biological Agriculture & Horticulture* 23: 59-72.
- Smith RF. 1972. The Impact of the Green Revolution on Plant Protection in Tropical and Subtropical Areas. *Bulletin of the Entomological Society of America* 18: 7-14.
- Sola-Guirado RR, Castillo-Ruiz FJ, Jiménez-Jiménez F, Blanco-Roldan GL, Castro-Garcia S, Gil-Ribes JA. 2017. Olive actual “on year” yield forecast tool based on the tree canopy geometry using UAS imagery. *Sensors* 17: 1743.
- Song B, Jiao H, Tang G, Yao Y. 2015. Combining repellent and attractive aromatic plants to enhance biological control of three tortricid species (Lepidoptera: Tortricidae) in an apple orchard. *Florida Entomologist* 97: 1679-1689.
- Song B, Han Z. 2020. Assessment of the biocontrol effects of three aromatic plants on multiple trophic levels of the arthropod community in an agroforestry ecosystem. *Ecological Entomology* 45: 831-839.
- Stern WR. 1993. Nitrogen fixation and transfer in intercrop systems. *Field Crops Research* 34: 335-356.
- Souza SNG, Piedade MTF, Demarchi LO, Lopes A. 2021. Implications of global climate change for the development and ecological interactions between two key Amazonian aquatic macrophytes. *Acta Botanica Brasilica* 35: 111-121.
- Tang GB, Song BZ, Zhao LL *et al.*, 2013. Repellent and attractive effects of herbs on insects in pear orchards intercropped with aromatic plants. *Agroforestry Systems* 87: 273-285.
- Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. *Nature* 418: 671-677.
- Villa F, Oliveira AF. 2012. Origem e expansão da oliveira na América Latina. In: Oliveira AF (ed.). *Oliveira no Brasil: tecnologias de produção*. Belo Horizonte, Epamig. p. 21-38.
- Werker E. 1993. Function of essential oil-secreting glandular hairs in aromatic plants of Lamiaceae – a review. *Flavour and Fragrance Journal* 8: 249-255.
- World Weather Online. 2021. Aiuruoca Climate Weather Averages. <https://www.worldweatheronline.com/aiuruoca-weather-averages/minas-gerais/br.aspx>. 17 Oct. 2021.
- Zhang Y, Han M, Song M *et al.*, 2021. Intercropping with aromatic plants increased the soil organic matter content and changed the microbial community in a pear orchard. *Frontiers in Microbiology* 12: 616932.
- Zhang Z, Luo Z, Gao Y, Bian L, Sun X, Chen Z. 2014. Volatiles from non-host aromatic plants repel tea green leafhopper *Empoasca vitis*. *Entomologia Experimentalis et Applicata* 153: 156-169.
- Zhang Z, Zhou C, Xu Y, Huang X, Zhang L, Mu W. 2017. Effects of intercropping tea with aromatic plants on population dynamics of arthropods in Chinese tea plantations. *Journal of Pest Science* 90: 227-237.

