



COMPOSITION AND CIRCADIAN DYNAMICS OF NECTAR SUGAR PRODUCTION IN WHITE AND PURPLE SOYBEAN FLOWERS



¹Gazzoni, D. L.; ^{2,3}Parpinelli, R.S.; ^{3,4}da Graça, J. P. Cotrim; ⁵G. S. da Silva, L. M. A.; ¹Zocolo, G. J.; ¹Hoffmann-Campo, C.B.

¹Embrapa Soja; ²Marialva Municipality Department of Agriculture; ³Former Embrapa-Bayer Post-Doc Student; ⁴Basic and Technological Sciences Department, National University of Chilecito, Chilecito, Argentina; ⁵Former MSc Student UNESP-Ilha Solteira.

INTRODUCTION

Approximately 90% of plants, including 75% of all domesticated crops, benefit from pollinators. Soybean [*Glycine max* (L.) Merrill] is only partially dependent on cross-pollination, as it is an autogamous and self-pollinated leguminous plant. In addition, soybeans are partially cleistogamic, meaning that flowers are broadly self-pollinated by the time of anthesis. However, their stigma remains receptive for approximately six hours, and the anatomical features of soybean flowers allow pollination by biotic agents, such as insects, predominantly several species of bees.

Thus, like other pollinated crops, soybean plants can benefit from diverse pollinator communities. The chemical composition of the nectar of soybean flower is crucial for mediating plant-pollinator interactions, as it directly influences pollinator visitation and plant reproductive success. Plant-pollinator interactions are traditionally assumed to be a binary system in which both partners obtain a continuing mutual benefit, such as food resources on the pollinators' side and reproduction on the plants' side.

This study investigated the hypothesis that nectar chemistry affects pollinator behavior by analyzing sugar and amino acid profiles in the nectar of six Brazilian soybean cultivars.

METHODOLOGY

Six soybean cultivars were sown in open-field plots, allowing free visitation by honey bees. Three cultivars presented purple flowers, and three white flowers. When the plants reached the full flowering stage (R2), we collected the nectar produced by the flowers of each cultivar on a daily basis.

NMR analyses were performed at the Multiuser Laboratory of Natural Products Chemistry of Embrapa Agroindústria Tropical, located at Fortaleza, Ceará State, Brazil. The NMR spectra were obtained at 600 MHz via DD2 NMR/MRI Console (for the ¹H nucleus) equipment and fitted with an NMR probe (Agilent Technology) with a 5 mm internal diameter (¹H-¹⁹F/¹⁵N-³¹P), reverse detection, and a z-axis field gradient.

After characterization, the compounds (sugars) were quantified via NMR integration signals on the basis of the reciprocity among signals and the amount of the compounds in the samples, establishing a correlation with a reference sample of known concentration. Multivariate data evaluation methods were applied to the measured variables via the ChemoFace to address the variability of the samples.

RESULTS

The results of the NMR spectroscopy analysis revealed that soybean nectar is predominantly composed of sucrose, α-glucose, β-glucose, and fructose, alongside with amino acids such as tyrosine and phenylalanine, which play biochemical and ecological complementary functions. The distinction between the α- and β-anomers was based on chemical shifts, with α-glucose detected at 5.2–5.3 ppm and β-glucose at 4.6–4.7 ppm.

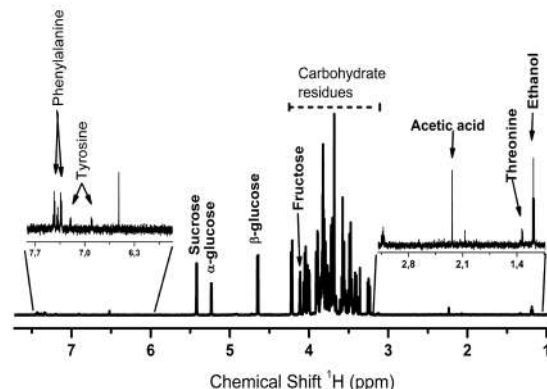


Figure 1 – ¹H NMR spectrum of nectar extracted from soybean flowers highlighting the prominent metabolites identified in all analyzed samples. The expanded regions display clear signals attributed to the amino acids phenylalanine, tyrosine, and threonine, as well as compounds such as sucrose, α- and β-glucose, fructose, carbohydrate residues, acetic acid, and ethanol. This study presents chemical shifts in parts per million (ppm).

Multivariate analyses, including principal component analysis (PCA), highlighted variations in sugar composition between soybean cultivars and pollination scenarios, with greater sugar accumulation in the absence of bees.

Our results spotlighted the adaptive importance of nectar chemistry in shaping plant-pollinator dynamics and its implications for optimizing pollination efficiency in agricultural systems. This study highlights the importance of integrating nectar composition into genetic breeding strategies to support pollinator populations to improve crop productivity.

CONCLUSIONS

The results revealed that soybeans produced significant amounts of nectar of high quality.

PCA revealed that nectar sugar profiles vary according to soybean cultivar and pollination status. In the absence of bees, sucrose and total sugar accumulate, suggesting an adaptive “storage” mechanism, whereas foraging rapidly depletes these reserves.

Nectar secretion follows a pronounced circadian rhythm, peaking between 08:00 and 11:00 AM, coincident with maximal anthesis, highlighting the importance of synchronizing breeding strategies with the natural timing of floral activity, supporting the theory that soybeans are partially dependent on biotic pollination, which increments its yield.

The authors are thankful to BAYER for funding this study through the Embrapa-BAYER agreement #10200.14/0059-7; to ABELHA for funding the participation in Apimondia; to the students of the Chemical Ecology laboratory at Embrapa Soybean and to the GPBee of the Universidade Estadual de Maringá, for their invaluable collaboration.

Decio Luiz Gazzoni¹, Rejane Stubbs Parpinelli¹, José Perez Da Graça¹, Lorena Mara Silva², Gustavo Dos Santos Cotrim¹, Guilherme Julião Zocolo¹, Clara Beatriz Hoffmann-Campo¹

¹Chemical Ecology Lab, Embrapa Soybean, Londrina, Brazil

²Embrapa Tropical Agriculture, Fortaleza, Brazil

Plant–pollinator interactions have traditionally been assumed as a binary system, in which both partners should obtain a continuing benefit, as food resources on the pollinators' side and reproduction on the plants' side. Nectar is the primary reward for pollinators visiting plants, and calories from nectar allow bee growth and development. Nectar pathway has a complex physiology and polygenic control, as well as strong environmental variability. The chemical composition of soybean flower nectar plays a critical role in mediating plant-pollinator interactions, by directly influencing pollinator visitation and plant reproductive success. Basically, nectar is a single sugars-watery solution that can easily be ingested, digested and absorbed, and thus it is a very cost-effective alimentary resource for a variety of animals. In long-living flowers, nectar is a refilled resource, secreted daily in the same flower, after being removed by pollinators (replenishment). This study investigates the hypothesis that nectar chemistry affects pollinator behavior by analyzing the sugar and amino acid profiles of soybean nectar under different conditions. The results revealed that soybean nectar is predominantly composed by sucrose, α -glucose, β -glucose, and fructose, alongside amino acids such as tyrosine and phenylalanine, which play complementary biochemical and ecological functions. Multivariate analyses, including Principal Component Analysis (PCA), highlighted variations in sugar composition between soybean cultivars and pollination scenarios, with higher sugar accumulation in the absence of bees. In contrast, sugar depletion in the presence of bees reflects the result of bee foraging activity. No significant differences in sugar composition were observed between white and purple flowers, indicating that floral color may not independently influence nectar composition, thus bee attraction and fidelity. These findings indicate the adaptive significance of nectar chemistry in shaping plant-pollinator dynamics and its implications for optimizing pollination efficiency in agricultural systems.