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Could Fire Severity Promotes the Biosynthesis of Bioactive Compounds As A Strategy to Enhance the Plant Survival? †

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Abstract: Fire causes effects on diverse aspects of plant functioning and development, many of them linked to survival. However, the response of native vegetation to this disturbance possibly reveals a plant strategy to tolerate fire linked to the biosynthesis of compounds like chlorophylls and secondary metabolites. The aim of this study was to evaluate whether fire severity could promote the biochemical tolerance to fire by influencing the biosynthesis of chemical compounds. To test this, six woody species from the Chaco region were exposed to an experimental burn of medium severity at fire season ending in the study area. In this burn, individual plots for each plant were established. Fire severity was estimated visually as the burnt biomass of each plant, which was considered as the percentage of the loss of aboveground biomass. Then, the biochemical plant response to fire was studied, through the changes in the concentration of photosynthetic pigments (chlorophyll and carotenoids), and secondary metabolites (phenolic compounds and tannins). The metabolites quantification was carried out by using spectrophotometric methods. As results, a strong correlation was found between the biosynthesis of metabolites in response to fire and the amount of burnt biomass during the experimental burns. This correlation could be considered as an indicator of the burnt plant response to stress. In our results, shrubby species showed both the higher amount of burnt biomass and the enhanced biosynthesis of compounds in the resprouts post-fire, which could be related to the capacity of these species to stablish in disturbed environments. Our study provides new insights into the understanding of the plant strategies to fire tolerance and resilience in natural environments.

Keywords: bioactive compounds; fire; fire severity; plant response to fire; plant survival

1. Introduction

The fire impact on vegetation depends mainly on three factors, the characteristics of the fire event, the plant storage reserves to regrowth post-disturbance, and the growth form of the species [1]. Fire tolerance is usually considered as the survival and regeneration capacity after fire. Accordingly, the plant response to the disturbance is closely related to the fire severity [2]. This severity includes the intensity and duration of the event and it indicates the degree to which

vegetation has been affected by this disturbance. In particular, burnt biomass is considered as a measurement of fire severity [3].

Due to the loss of aerial biomass during the disturbance, plants active the production of resproutings as a survival strategy to recover their vegetative structure [4]. This disturbance response is conditioned by the availability of biochemical reserves in bud banks and meristems. Therefore, the recovery of photosynthetic efficiency is closely related to the plant biochemical composition, as these compounds allows the production of resproutings and influence the plant survival [4,5].

A high availability of plant reserves allows a high investment in defense and regeneration structures to guarantee their establishment post-disturbance [4]. Moreover, as the main defense mechanism, plants synthesize bioactive compounds whose function is to grant them protection against environmental changes generated by disturbances [6,7]. These compounds as the photosynthetic pigments (chlorophylls and carotenoids) and the secondary metabolites (as phenolic compounds and tannins) contributes to enhance the plant response against the biotic and abiotic stress caused by the environmental changes. Consequently, the link between burnt biomass during a fire event with the plant biochemical response, also, could be considered as an indicator of the burnt plant response to stress and, besides, it could also influence the plant survival.

In this study, the fire severity effect on the biosynthesis of bioactive compounds as photosynthetic pigments and secondary metabolites was evaluated. A positive correlation between fire severity (measured as the burnt biomass) and the biosynthesis of bioactive compounds could be considered as an indirect bioindicator of the plant tolerance to fire.

2. Methods

2.1. Study area

The Argentine Western Chaco Region is characterized by a seasonal semiarid climate and fire has been a frequent ecological event from late 19th century [8]. Our study site was located in INTA's 'Francisco Cantos' Experimental Station in Santiago del Estero, Argentina (28°030S, 64°150E). This experimental field has an area of approximately 8000 ha and includes the typical vegetation units of the Western Chaco Region: forests, savannas, grasslands and shrubs in different states of conservation. The selected woody species were: Schinopsis lorentzii (tree), Aspidosperma quebracho-blanco (tree), Sarcomphalus mistol (tree), Celtis ehrenbergiana (shrub), Atamisquea emarginata (shrub), and Schinus johnstonii (shrub), due to their representativeness in the study area.

2.2. Experimental burn and biochemical measurements

An experimental burn was carried out in October 2016 during the flammability peak of the Chaco Region [9]. The essay had a completely randomized design with individual plots 2 m x 2 m. Five replications per species were used. Each replication consisted of an individual plant (DBH < 15, total height < 2 m) located in the center of the plot. The experimental burn was of medium severity (fine fuel load 4000 Kg DM ha-1). Burnt biomass was estimated visually by two operators.

For chlorophyll and carotenoid contents, samples of each burnt plant were collected six and twelve months after the burn. As control, samples of five unburnt plants were randomly collected in the same site, and dates. The determinations were performed according to the methodology proposed by Coria-Cayupán [10]. To evaluate the long-term effect of phenolic compounds and tannins in the plant response to fire, samples of each burnt plant were collected twenty-four months after the experimental burn. Similarly, as control, samples of five unburnt plants were randomly collected in the same site and date. The assessments of these compounds were performed according to García [11].

2.3. Statistical analysis

A principal component analysis (PCA) was performed using the total contents of the post-fire biosynthesized metabolites studied in this work. The first axis of the PCA was considered as the biosynthesis of bioactive compounds value. The correlation between the burnt biomass and the

bioactive compounds was performed through a Pearson's correlation coefficient. The statistical software used was Infostat/2017 (InfoStat Group, Universidad Nacional de Córdoba, Argentina) with an α= 0.05.

3. Results and discussion

Results showed that the experimental burn caused a variation in the bioactive compounds evaluated within a short temporal scale (short term effect). The first two axes of the PCA performed to evaluate the biosynthesis of bioactive compounds using the total contents of the post-fire biosynthesized metabolites explained 71% of the data. The Pearson's correlation coefficient between burnt biomass and the first component of the biosynthesis of bioactive compounds showed a significant association between them (Pearson's P= 0.40, P-value= 0.0014; Fig. 1).

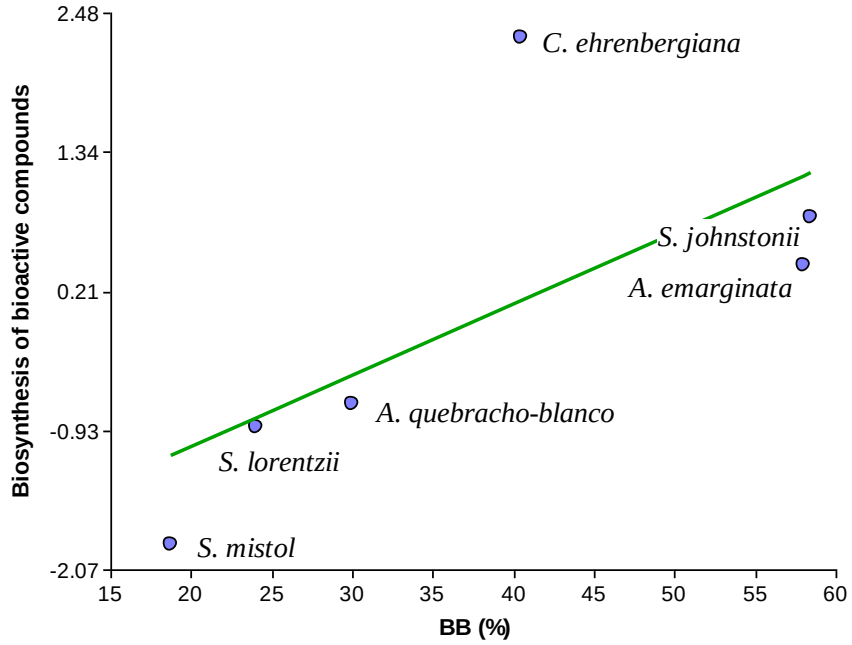

Figure 1. Correlation between the burnt biomass (BB) during the experimental burn and the first component of the biosynthesis of bioactive compounds. Green line show where points would have a perfect correlation between the burnt biomass and the biosynthesis of compounds. Species below the line had a higher content of bioactive compounds in relation to the percentage of biomass consumed during the experimental burn, while species above the line had a greater loss of biomass during the burn compared to the content of bioactive compounds biosynthesized post-fire.

Results about burnt biomass suggested different fire severity among species studied, showing that shrubby species (*C. ehrenbergiana*, *A. emarginata* and *S. johnstonii*) were more seriously affected than tree species (*S. mistol*, *S. lorentzii*, and *A. quebracho-blanco*). Additionally, the first-mentioned species showed the highest values of biosynthesis of compounds in response to fire. These results suggest that fire severity could affect the post fire plant responses observed in our study.

Our results suggest that in low-intensity events (as the experimental burn performed in this work), the correlation between the biosynthesis of bioactive compounds and the amount of burnt biomass during the experimental burn, could be considered as an indicator of the burnt plant response to stress and indirectly, as a bioindicator of the plant tolerance to fire. Thus, this study allows us to suggest that its association contributes to the post-disturbance vegetation establishment.

The highest values of the bioactive compound biosynthesis of shrubby species could be related to the investment in defensive structures to protect against physical or mechanical disturbances as herbivory, fires, among others. These results could contribute to explain the capacity of these species to stablish in disturbed environments [12], as the main function of these compounds is the plant

protection against environmental stress [13]. The greater availability of plant reserves allows a greater investment in defense and regeneration structures to guarantee their establishment post-disturbance [4].

4. Conclusions

These findings confirm our hypothesis suggesting that fire severity could influence the biosynthesis of chemical compounds which could indirectly enhance the plant survival. Our results showed that a fire event as the experimental burn carried out in this study, could produce variations in the biosynthesis of bioactive compounds, in response to the environmental stress caused by the disturbance. Accordingly, these compounds could be considered as indirect bioindicators of plant tolerance to fire, due to the strong correlation between the burnt biomass and the post-fire biosynthesized metabolites. The increase in the bioactive compound concentrations contributes to protect the burnt plants in the post-fire environmental conditions, as a main defense mechanism against oxidative stress conditions.

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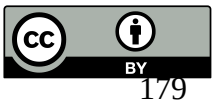

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