Orchard Understory Species Diversity in Relation to Orchard Age and Soil Factors (in Ibadan, Southwestern Nigeria)

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Abstract

The relationship between species richness and environmental variables enhances valid conclusions on the effect of biodiversity on ecosystem processes. Extant literatures exist on the relationship between species richness, a measure of biodiversity and ecosystem functionality. Therefore, this study examined understory plant species diversity of Citrus orchards (*Citrus sinensis*) between the young (twenty years) and the old (forty years) in relation to soil parameters. Direct method of gradient analysis was used whereby sample plots were randomly located and marked at the study site and understory plant species per unit area recorded and categorized. A set of 30 quadrats and 39 quadrats were taken in the young and old orchards respectively. The collected data in the undergrowth were subjected to an ecological analysis. The data were analyzed using Simpson's index, student T-test and canonical correspondence analysis (CCA). The result of the diversity index showed that the older orchards had greater species dominance than the younger ones. The t-test shows a significant difference between orchards ($t = 0.03$, $P = 2.27$). The placement of environmental variables in CCA showed that the first gradient (that is, the main explainable variation in floristic composition) was positively correlated with pH, total nitrogen and negatively with clay content.

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1 Introduction

Ecological communities function and are sustained mostly based on the health of species diversity. A number of factors affect small-scale species diversity, including environmental factors such as disturbance, environmental heterogeneity and resource availability; geographic factors such as the regional species pool, dispersal distance and ease of dispersal, as well as biological factors such as predation, competition and facilitation. The significance of these factors varies depending on the scale of observation. Also, small-scale diversity can influence features of ecosystem function including productivity and stability. The pattern of species diversity along the environmental gradient has been a subject of inquiry in biogeography (Fashae et al. 2018). Quite a huge number of experiments has been performed to check out the relationship between species richness (a measure of biodiversity) and ecosystem function. Basically, understanding the relationship between species richness and environmental variables helps us to draw valid conclusions on the effect of biodiversity on ecosystem processes especially across orchards of different ages (Naffar et al. 2013; Meddad-Hamza et al. 2017). Therefore, this study examined plant species diversity of undergrowth under citrus orchards (*Citrus sinensis*) of ages between 20 (young) and 40 (old) years in relation to soil nutrient.

2 Study Area

The study site is located within the National Horticultural Research Institute (NIHORT), Ibadan, Oyo State, Nigeria. The Institute is located at Latitude 7° 23′ and 7° 25′N and Longitude 3° 50′ and 3° 52′E. It is situated on a 350 ha of land. NIHORT is located within Ibadan and falls within the humid tropical zone which covers about 21% of the total landscape of Nigeria (Iloeje 1981). There are two main climatic seasons: tropical wet and dry climate with a lengthy

wet season and relatively constant temperatures throughout the course of the year. The sites are well drained by two rivers. The dominant soil types are the ferruginous group of tropical soils. Agricultural land use type in the area is mainly for the production of horticultural crops such as vegetables, fruits and ornamentals. there are orchards of *Magnifera indica* (Mango), *Citrus* spp. (Orange, Lemon, Lime, Grapes and Mandarins), *Treculia africana* (Bread Fruit), *Psidium guajava* (Guava), *Chrysophylum albidum* (African star apple) *and Irvingia gabonensis* (Bush Mango). In the dry season, vegetable production is extensively practiced in the valley bottom. The young citrus orchard area extent is about 4659.4 m² while the old citrus orchard area extent is about 7555.5 m². The citrus is planted along 9 rows, 7 m apart both horizontally and vertically.

3 Methods

The gradient analysis using sample plots randomly located and marked at the study site was performed. Understory plant species per unit quadrat (50 cm × 50 cm) were recorded and categorized. The geographic positions of the quadrat points were taken and mapped. A total of thirty and thirty-nine quadrats were taken in the young and old orchards respectively. Data collected in the undergrowth were subjected to an ecological analysis. After collecting the vegetation data, a volumetric soil sample at 0–30 cm depth was collected randomly with a soil auger at the center of each sampled quadrat. Soil physicochemical parameters of pH, organic carbon, organic matter, total nitrogen, copper, zinc, magnesium, phosphorus and particle size distribution were analysed. The data were analysed using Simpson's index, student T-test and canonical correspondence analysis (CCA). For interpretation (CCA), each site was labelled with reference to its age. The points labelled Y and O are the points within the understory of the young and older orchard, respectively. The length of the environmental arrows indicates how important that variable is and how well the values of the variable are displayed in the biplot of the environmental variables and sites. This follows the fact that the length is equivalent to the maximum rate of change of the variable; across the diagram, variables with short arrows have little variation.

4 Results

The understory plant species found under the younger citrus orchard were grouped into 25 families with about 59 species. Out of these, the families with the highest dominance in terms of number of species were *Poaceae* (29%), *Asteraceae* (27%), *Fabaceae* (18%), *Amaranthaceae* (13%) and *Acanthaceae* (13%). As expected these families dominated the younger orchards because they were widespread under cultivated lands and field crops. The older citrus orchards had 61 understory species. The dominant species within the older orchard in terms of dominance are *Setaria barbata, Euphorbia graminea, Oplismenus burmannii, Althernanthera brasiliana* and *Asystasia gangetica*. The families with the highest dominance in terms of number of species were *Poaceae* (34%), *Acanthaceae* (22%), *Amaranthaceae* (13%), *Euphorbiaceae* (10%), *Asteraceae* (8%), *Vitaceae* (7%), *Fabaceae* (6%), and *Acanthaceae* (13%). The result of the Simpson diversity index showed that the older orchard had greater species richness (0.91) than younger orchard (0.88). The *t*-test shows a significant difference of 0.03 ($p = 2.27$). Implying that there is a significant difference between the means of the two ages of the orchards.

The placement of environmental variables shows that the first gradient (that is, the main explainable variation in floristic composition) is positively correlated with pH, total nitrogen and negatively with clay content percentage. Likewise, some species composition had a negative correlation with Fe and Mn and a positive correlation with Zn, Na and other elements. The species points and the environmental arrows together represent weighted averages, typically giving a summary of the species along each of the environmental variables. By projecting the species points on the arrows for pH (Fig. 1), we can infer that *Althernanthera brasiliana* and *Centrosema pubescens*, of all the displayed species, have the highest weighted averages for pH and for this reason occur at high pH values and *Talinum triangulare* at lower than average values. On the other hand, species close to *Tridax procumbens* have low weighted average for Mg and Avail. P.

5 Discussion

The species count between the young and old orchards is quite close but differences exist between species across the orchards. The Simpson index suggests significant difference between their diversities. It was observed that there were endemic species in each of the orchards. The result of the t-test implies that age significantly influenced understory diversity. This suggests that age affects the species diversity of understories to a large extent. Newer species are colonizing the younger orchards as a result of continued cultivation and management of the younger understory. As regards the canonical correspondence (Fig. 1), it is possible to infer relative abundance from the diagram but how exactly this should be done is still a topic for discussion in literature (Ter Braak et al. 1994). We therefore observed that sites that contain a particular species are spread around the point of that species. In Fig. 1, *Ageratum conyzoides* is in the middle
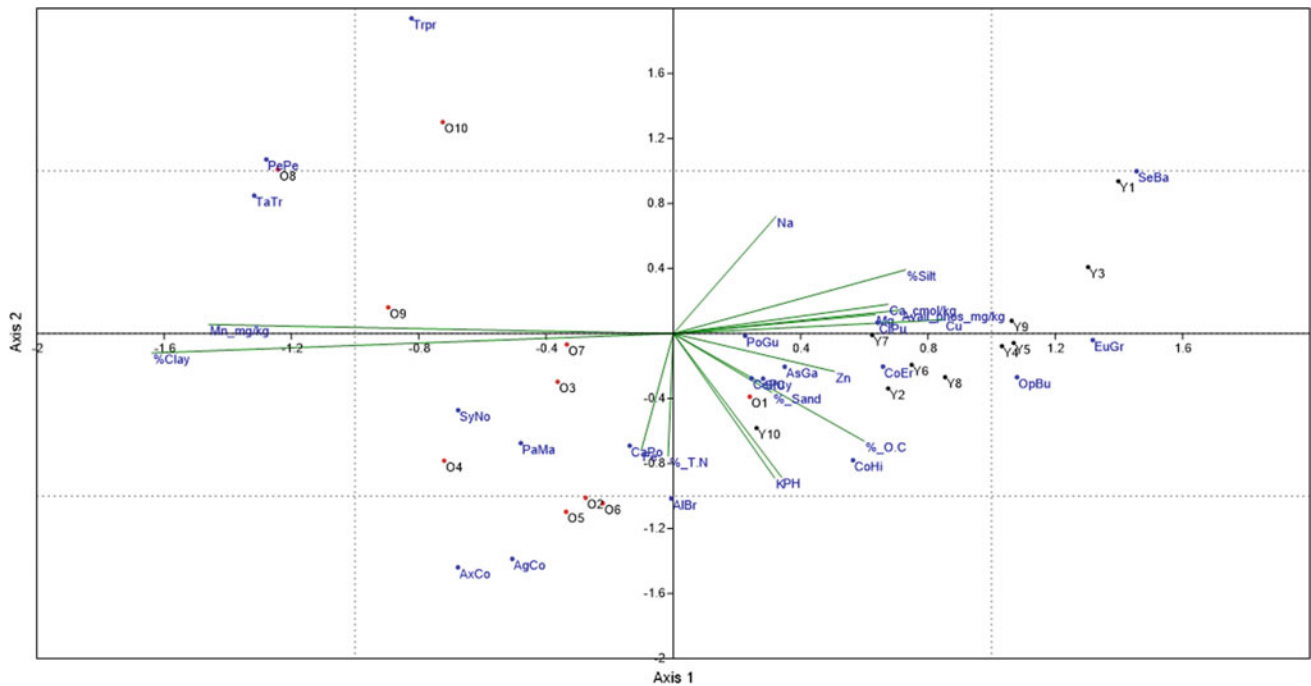
Fig. 1 Canonical correspondence analysis displaying interrelationship between species under orchards of different ages and environmental factors

of the older orchard depicted by O and so the distribution is centered around these points. Also, the place of *Cissus pulpunea* indicated that the species distribution is confined to the young orchard.

6 Conclusion

From the foregoing, we are able to point out the most important soil nutrients factors responsible for plant species distribution of Citrus understory within NIHORT. Further, the research has shown how integrating a temporal dimension into questions that are traditionally spatial can facilitate more rigorous testing of processes we are interested in, as well as bringing about a generation of new, testable hypotheses that would not be evident through the use of spatial approaches alone. This research should be expanded to include other environmental variables such as climate and altitudinal factors. The variability of the soil factors can also

be investigated to provide a template useful for informed decision on soil fertilizer application and conservation.

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