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# Effect of different germination processes on belowground and aboveground productivity in mature Coffea arabica

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## ABSTRACT

This was the first study in Monteverde, Costa Rica to look at how the agricultural method used during the germination phase affects the productivity of a mature *Coffea arabica.* It was thought by local farmers that a plant germinated in the ground and then transplanted would have more fine root biomass than a plant that is germinated in a polybag and then transplanted. Traditional farming practices have shown that when coffee is transplanted from the ground to another location; the main root is often cut, yielding more secondary fine roots. In contrast, many experiments have found that polybags increase a plant's productivity by protecting root growth (Shu-guang et al. 2003, Gera et al. 1998). Fine roots are the source of nutrient uptake in a plant, thus, if a plant had more fine roots it should be more productive. Viewing the germination technique as a form of natural disturbance to the plant, this study measured the plant's response in terms of productivity both belowground and aboveground. More shoots were produced by plants germinated in the ground in comparison to those germinated in bags ($p < 0.05$) indicate that the germination technique does affect aboveground productivity, though no affect was found on belowground productivity ($p = 0.7055$).

## RESUMEN

Éste es el primer estudio que investigo cómo se afecta la productividad de *Coffea arabica* mediante el método agrícola usado durante la fase de la germinación Una planta germinada en la tierra y después trasplantada podría tener más biomasa de la raíz fina que una planta que se germina en una bolsa plástica y después se trasplanta. Las prácticas agrícolas tradicionales han demostrado que cuando el café se trasplanta de la tierra a otra localización; la raíz principal se corta a menudo, rindiendo más raíces finas secundarias. Las raíces finas son la fuente de nutrientes en una planta, así, si una planta tiene raíces más finas es más productivo. Viendo la técnica de la germinación como forma de disturbio natural a la planta, este estudio midió la respuesta de la planta en términos de la productividad abajo y sobre la tierra. Se produjeron más brotes de raíz en las plantas que germinaron en la tierra con respecto a las germinadas en las bolsas ($p < 0.05$) esto podria ser un indicador que la técnica de la germinación afecta productividad sobre tierra, aunque ningún efecto fue encontrado en productividad de abajo la tierra ($p = 0.7055$).

## INTRODUCTION

Currently there is a debate in ecology as to the importance of belowground and aboveground interactions to overall productivity. Mutualisms involving mycorrhizae, detritivore and arthropod decomposition, and plant physiological processes above and below the soil surface influence growth. In addition, above and belowground productivity is starting to be studied (De Deyne and Van der Putten 2005, Harmand et al. 2003, Porazinska et al. 2003), though certain specific processes still remain a mystery. Plants are the main bridge between the subsurface and aboveground realms (De Deyn and

Van der Putten 2005), thus studying their response to various local perturbations can help elucidate when, why, and how these interactions occur.

As an important agricultural product in many Latin American countries, the cultivation of *Coffea arabica* plays an integral role in local economies (Boucher 1993). There are various methods of growing coffee such as in full sun, in shade, with chemicals, without chemicals, with compost, or with fertilizers, but the period of germination is crucially important for the development of a strong dominant plant (Grubb 1977). Non-conventional farming such as Organic or Fairtrade often relies on natural remedies, instead of chemicals to maintain and increase their yields. In traditional coffee farming, there are two practices used during germination and the early stages of the plant's life. In one method, the seed is placed in a plastic bag, or polybag, until it has reached maturation after approximately 50 days; then, it is transplanted into the ground. The polybag is thought to protect the seedling from root predators, unfavorable soil conditions, and it also minimizes disturbance to the plant during transplantation (pers.conv Santa Maria 2008). The other method involves placing the seed in a protected area on the ground, or seed bank, and after 50 days it is transplanted into the area of cultivation. During transplantation the roots are partially cut with a machete and must regenerate. While this process can compromise the plant if the roots are not re-grown quickly, it also encourages surface extension of secondary roots rather than vertical extension of a solitary root, which occurs with the bag-germinated plants (Hipps et al. 1996). Horizontal rooting and development of fine root mass can be important for essential nutrient uptake; especially in tropical regions where the majority of nutrients are located in the top layers of the soil (Kothari et al. 2005, Lynch 1995).

The purpose of this project is to determine if disturbance in the form of germination technique influenced the belowground and thus aboveground productivity of *Coffea arabica*. Measurements were made of the relative horizontal fine root biomass of plants germinated in the ground and of plants germinated in polybags. This was paired with information gathered on the aboveground productivity of the plants to determine if, in fact, bag-germination produces less belowground biomass and if this affects the overall aboveground productivity of the plant.

# METHODS

## Study Site

The study took place on two coffee farms, the Santa María farm and the Torres farm, found in a tropical wet forest, approximately 1300 meters above sea level, in Cañitas, Costa Rica. Both farms were transitioning from conventional farming to organic agricultural production, thus fostering similar microhabitats. Neither farm had used chemical additions for the past three years of cultivation. The farms were producing five to seven year-old, full-sun variety *Coffea arabica* in approximately two-hectare plots. The only perceivable difference between the farms was the method of plant germination; the Santa Maria farm germinated its plants in plastic bags, and the Torres farm germinated its plants in the ground. Thus, ten mature coffee plants were selected from each farm for analysis.

**Belowground Analysis**

Four soil samples were taken using a standard soil corer at random intervals approximately ten centimeters from the focal plant to a depth of approximately 15 cm. At the time of sampling, the upper leaf debris and hummus layer was removed and the four cores were pooled for each plant in a Ziploc™ bag. The soil was then dried at 70˚C for twenty-four hours and massed. The roots were extracted from the soil by soaking the pooled soil samples in water and sieving through a two-millimeter screen. Two successive washings of the remaining soil followed this. The roots were rinsed in distilled water, and were separated from the organic debris using forceps. The roots were dried at 70˚C and massed using an analytical balance (Dossa et al. 2007). In this way, the relative fine root biomass per gram of soil was determined for all ten plants that were ground germinated and all ten that were container germinated.

**Aboveground Analysis**

Due to the age of the plants and to avoid damage, only the shoots were counted to assess aboveground biomass. *Coffea arabica* does not fruit until approximately eight years of age. Using a hand counter, the shoots were counted on the same twenty plants from which soil was taken. These numbers were then used to reflect the aboveground productivity of the differently germinated plants.

**Statistical Analysis**

A Mann-Whitney non-parametric comparison test was used to determine if there was a significant difference between the biomass of plants that are germinated differently. One test compared the fine root mass and another compared the number of shoots. A correlation analysis, Spearman's Rank test, was also used to determine if belowground biomass and above ground biomass were correlated.

## RESULTS

There was no difference in productivity between germination treatments for belowground biomass (Fig 1,U = 45, p = 0.7055, n = 10), but there was a difference in productivity found for the aboveground biomass between treatments (Fig 2, U=0, p = 0.0001573, n = 10). The median values of belowground biomass for each treatment were very similar (bag germinated = 0.0022, ground germinated = 0.0018) and there was complete overlap of the data range with high variability of root biomass for bag germinated plants (Fig. 1). The boxplots of aboveground biomass show that the ground germinated *C. arabica* had more shoots than the coffee germinated in bags (Figure 2). There was a difference in the medians (bag

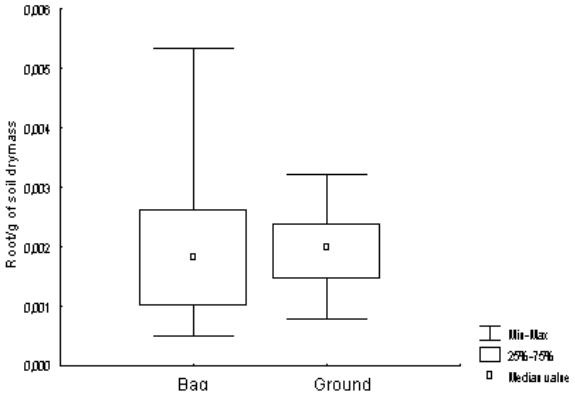


FIGURE 1. The amount of fine rootmass of bag germinated *Coffea arabica* plants compared to that of ground germinated plants. Using a Mann- Whitney U test, there was not a significant difference in the rootmass for the differently germinated plants (U = 45, p = 0.7055, n = 10).

germinated = 57.5, ground germinated = 92.5) despite moderate variation in the ranges of the data.

There was no correlation between belowground and aboveground biomass for the germination treatments (Figure 3). The figure shows a scattered, non-linear distribution ($\rho = 0.17$, $p = 0.4733$, $n = 10$) with only 17% of the variation in belowground biomass explaining variation in aboveground biomass.

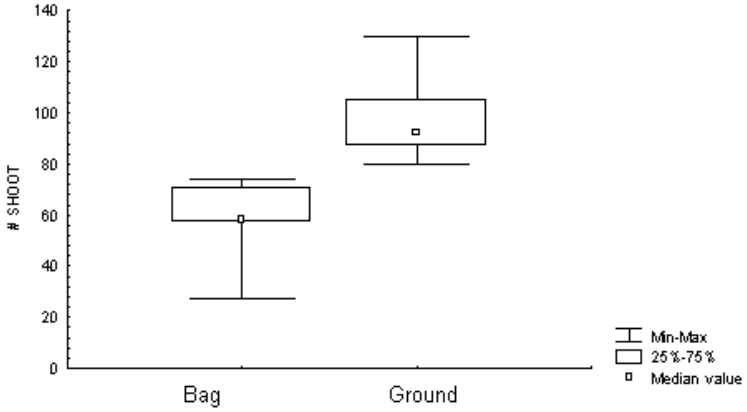


FIGURE 2. The number of shoots of bag germinated *Coffea arabica* plants compared to those of ground germinated plants. Using a Mann- Whitney U test, there was a significant difference in the number of shoots for the differently germinated plants ($U = 0$, $p = 0.000157$, $n = 10$).

## DISCUSSION

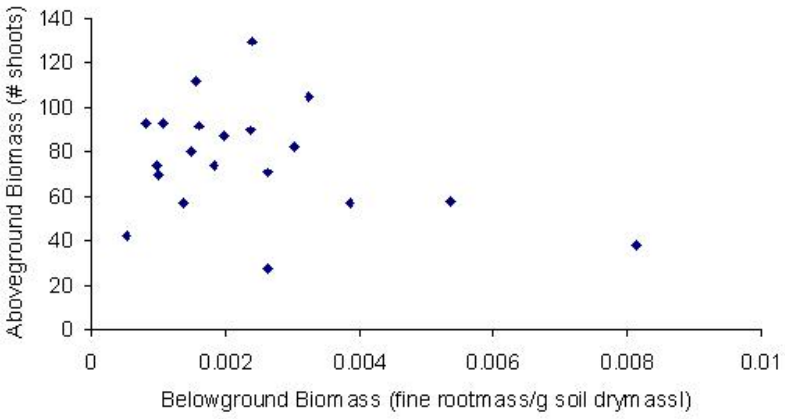


FIGURE 3. Spearman rank correlation between belowground biomass and aboveground biomass. A correlation was not found between rootmass and number of shoots for *Coffea arabica* ($\rho = 0.17$, $p = 0.4733$, $n = 20$).

While the results of this study did not validate a direct effect of germination method on coffee productivity, it does promote further speculation about the belowground and aboveground interactions of *C. arabica*. The belowground biomass was not different for differently germinated coffee plants. This leads one to believe that germination method does not affect the development of fine rootmass. Explanations for this could be that either transplantation effects, from the ground or a bag, are equally disruptive, or over time, differences in these effects are minimized. Another possibility is that germination technique does influence root growth, but due to the difficulty of measuring belowground biomass these effects were not detected. Very little fine root biomass was obtained from the coring, and, though, there was little to no growth around the coffee plants, the roots were not identified to species, possibly influencing the results.

One interesting outcome of this study is that germination method does seem to affect aboveground productivity of coffee plants. Although increased belowground productivity for ground germinated plants was not found, the differences in aboveground

productivity indicate that germination technique does matter. Plants that were germinated in protected ground or seedbanks and then transplanted had more shoots than plants that were germinated in polybags and then transplanted. Thus, the traditional theory that transplantation from the ground encourages the plant to uptake more nutrients is probable (Hipps et al. 1996). It is possible that ground germination and transplantation does promote more horizontal root development, and thereby more nutrient uptake, but this might only be seen in the early stages of the plant's development. Over time, ground and bag germinated plants might become functionally equivalent belowground, but aboveground the ground germinated plants will show the advantage. In addition, germination technique might affect aboveground productivity through processes other than nutrient sequestration. Ground germination is thought to be more disruptive, but this could be an advantage such that plants that survive to adulthood are more hardy, fast growing, or productive as a result of disturbance.

The results of this study indicate how little is known about the belowground and aboveground interactions of plants. The analysis of germination technique effect on productivity of *C. arabica* suggests that disturbance can be reflected in aboveground but not belowground productivity. Furthermore, the effect of disturbance on overall plant productivity is of utmost importance to agriculturists that depend on maintaining aboveground productivity to meet a market demand.

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## LITERATURE CITED

Boucher, D. H. 1983. Coffee. *In*: Costa Rican Natural History, D. H. Janzen, (ed). The University of Chicago Press, Chicago, IL, pp. 86-88.

De Deyn, G. B. and W. H. Van der Putten. 2005. Linking aboveground and belowground diversity. Trends in Ecology and Evolution. 20.11: 625-633.

Dossa, E. L., E. C. M. Fernandez, W. S. Reid and K. Ezui. 2008. Above- and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. Agroforest Syst. 72: 103-115.

Gera, M., N. Gera, S. Sharma, A. S. Bhandari. 1998. Improved seedling quality of polybag plants: Use of mounted angle iron beds. Indian Forester. 124.2: 116-133.

Grubb, P. J. 1977. The maintenance of species- richness in plant communities: the importance of the regeneration niche. Biological Reviews. 52.1: 107-145.

Harmand, J-M., C. Forkong Njiti, F. Bernhard-Reversat and H. Puig. 2003. Aboveground and belowground biomass, productivity and nutrient accumulation in tree improved fallows in the dry tropics of Cameroon. Forest Ecology and Management. 188.3: 249-265.

Hipps, N. A., K. H. Higgs, L. G. Collard. 1996. The effect of irrigation and root pruning on the growth of sycamore (Acer pseudoplantanus) seedlings in nursery beds and after transplantation. Journal of Horticulture Science. 71.5: 819-828.

Kothari, S. K., C. Singh and Y. V. Kumar. 2005. Growth and yield of *Spilanthes acmella* roots and its cultivation economies as influenced by nitrogen and phosphorus application under semi-arid tropics. Journal of Medicinal and Aromatic Plant Sciences. 27.2: 283-286.

Lynch, J. 1995. Root architecture and plant productivity. Plant Physiology. 109: 7-13.

Porazinska, D. L., R. D. Bardgett, M. B. Blaauw, H. W. Hunt, A. N. Parsons, T. R. Seastedt and D. H. Wall. 2003. Relationships at the Aboveground- Belowground Interface: Plants, Soil, Biota, and Soil Processes. Ecological Monographs. 73.3: 337-395.

Shu-guang, J., Y. Zhong-yi, J. Wei-jun. 2003. The effects of nutrition polybag on the growth, N-fixation and heavy metal accumulation of Sesbania rostrata grown on Pb/Zn tailings. Journal of Tropical and Subtropical Botany. 11.1: 34-40.