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Architecture and yield relationship in hazelnut tree

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Abstract

Yield reduction over the years is a phenomenon that affects many fruit tree species, including hazel (*Corylus avellana*). Studying plant architecture could provide useful information for improving crop management, such as pruning, to reduce the impact of yield reductions. This study aimed to compare the relationship between bud composition and shoot length in hazel shoots. The experiment was carried out in January 2020 and 2021 in Deruta, Perugia (Italy). In 2020, 120 1-year-old shoots of *C. avellana* ‘Tonda di Giffoni’ were sampled. In 2021, the same observations were performed on lateral and apical 1-year-old shoots that had burst from parental buds in spring 2020. Depending on its length, each shoot was sorted into four categories: short (Sh) when shorter than 5 cm, medium (Me) when between 5 and 20 cm, long (Lo) when between 20 and 40 cm, and very long (VLo) when longer than 40 cm. For each shoot, shoot length, axillary and apical bud fate was recorded at each node: vegetative bud, latent bud, catkin, and mixed bud (V, B, C, and M, respectively). Percentage of lateral mixed buds was higher in longer shoots than in shorter ones while that of vegetative buds remained constant whatever the length. Fruit set, computed as the ratio between the number of nuts and the number of mixed buds, was significantly higher in Lo and VLo shoots. It was observed that the length of lateral proleptic shoots, developed in 2021, was related to the length of the bearer shoot from which it was developed. Proleptic lateral Sh shoots were the most frequent among all length categories while longer proleptic shoots (Lo and VLo) were originated only from Lo and VLo shoots. Managing tree architecture, considering a good balance between long and short shoots, and mixed and vegetative buds, could help control and prevent yield decrease in hazelnut trees.

Keywords

hazel, *Corylus avellana*, nut, branching, shoot length

Introduction

Yield reduction over years is an important phenomenon in hazel, compared to many other fruit tree crops where alternate bearing is more relevant (Monselise and Goldschmidt, 1982; Azarenko et al., 2005; Baldwin, 2015). Both, alternate bearing and yield reduction imply significant differences in production from one year to the other. They are influenced by genetics, environmental condition, and managerial practices (Sharma et al., 2019), but a significant role is played by the formation of

bearing organs (1-year-old shoots) of a sufficient length to initiate flowers and support fruit-bearing (Stevenson et al., 2000; Tombesi et al., 2011). In hazel, as well as in other crops such phenomena are strongly affected by the reduction of vegetative growth over two subsequent years (Monselise and Goldschmidt, 1982). Indeed, modifying tree architecture through pruning contributes to regulate the relationship between reproductive and vegetative activity, which is crucial to reducing the negative effect of inconstant bearing (Azarenko et al., 2005). Tree architecture is defined as the structure of the plant which is the result of the activity of the apical and lateral repetitions of the plant base unit: the meristem (White, 1984). The general behavior of the tree results from the position and the arrangement of reproductive and vegetative organs over the years (Costes et al., 2006). Studies that are crucial to obtain that information focus their analysis on shoot type (i.e. length, formation time, diameter), branching (i.e. position and fate of lateral buds), succession (i.e. fate of apical buds), organ development and form (i.e. phyllotaxy, shape) (Costes et al., 2014; Grisafi et al., 2021). Previous work suggested a relationship between flower density and shoot length (Tombesi and Farinelli, 2014), but authors did not track the evolution of the shoot characteristics over consecutive seasons. This work aims to relate hazel lateral bud fates, yield, and 1-year-old shoot length with the length of the shoots on which they were borne. The scope of the research is to use architectural information to support horticultural practices that can help in reducing inconstant bearing effects.

Material and methods

The experiment was carried out in Deruta, Perugia (Italy) in 2020 and 2021. In January 2020 120 one-year-old shoots of own-rooted *Corylus avellana* 'Tonda di Giffoni' plants, were chosen. The experimental orchard contained 140 hazel trees planted in 2014 at 4×4 m distances trained with a 'free vase' system. Plants were 6 years old and standard horticultural cares were applied. A selection of shoots was monitored. Shoots were sampled according to four length categories: short (Sh) when the length was less than 5cm, Medium (Me) when it was between 5 and 20 cm, long (Lo) when it was between 20 and 40 cm, Very-long (VLo) when it was more than 40 cm. Biometrical measurements (i.e. length in cm, number of nodes, and diameter) were taken on each selected shoot. During winter, bud fate at each node was recorded, from the base to the shoot tip. Four fates are possible in *C. avellana*: vegetative bud (V), blind node (B), catkin (C), and mixed bud (M). In the following year, mixed buds will originate, new mixed shoots composed of leaves and, in the apical position, the female inflorescence that will bear the nuts. In June 2020, on the same shoots, the number of nuts was recorded. Fruit set was computed, per each shoot, as the number of nuts per mixed bud. In January 2021, the same biometrical measurements and bud fate recording were performed on lateral and apical 1-year-old shoots derived from the buds that were recorded in 2020 without pruning the trees. Statistical analyses were carried out using RStudio (R Core Team, 2022). Proportion tests were used to test the difference of mixed and vegetative buds between parental classes and to test the difference of 2021 1-year-old Sh shoots and Me shoots, between parental classes with a significance level set at 0.05. Difference in the fruit sets among the different parental classes was tested using ANOVA and Tukey test with a significance level set at 0.05.

Result and discussion

A significant difference in proportions, both for mixed and for vegetative buds, was noticed in 2020 depending on the shoot length category (Figure 1). The percentage of mixed buds was significantly higher in longer shoots than in short shoots (VLo: 33.18%, Lo: 29.76%, Me: 30.63%, and 22.63%, respectively) while the proportions of vegetative buds were similar for all the shoot lengths except for medium shoots (22.54%). This indicates that the number of reproductive buds is related to shoot length. In Sh shoots the induction of mixed buds is reduced if compared to longer shoots. The influence of shoot length on flower differentiation led to a significant reduction of the yield potential on this type of shoots. Furthermore, Sh and Me shoots had a significantly reduced rate of nut set compared to Lo and VLo shoots (Figure 2).

The mean length of the lateral proleptic shoot developed in 2021 was linearly correlated to the length of the shoots from which they originated (Figure 3) with a slope value for the relation equal to 0.04 and an intercept of 1.39.

This produced a consistent shift in the 2021 1-year-old shoot population since the majority of them were Sh (<5 cm) whatever the length categories of the 2020 shoots (Figure 4).

Therefore, the percentage of 2021 1-year-old Sh shoot was lower in VLo class ($P < 0.05$) (Figure 2). 2021 Me 1-year-old shoots were present in all 2020 length categories, but more frequently from very long shoots (12.44%) than Sh (6.15%) or Me (5.26%) 2020 shoots (Figure 2). A small proportion of 2021 Lo and VLo shoots was born only from 2020 Lo (2021 Lo: 0.29%) and 2020 VLo (2021 Lo: 0.9% and 2021 VLo: 0.23%) shoots. The shift of 1-year-old shoots toward shorter length categories is common in many fruit crops such as apricot (Costes et al., 1992) and apple (Costes et al., 2003) and it is known as "ageing" (Meier-Dinkel and Kleinschmit, 1990). In hazel, this phenomenon seems to be more pronounced and rapid than in other crops such as pistachio (Stevenson et al., 2000).

Conclusion

In hazel trees, 1-year-old lateral shoots belong mostly to the short shoot type whatever the length of the shoot from which they were born. This causes a significant reduction in the number of mixed buds present in the subsequent year since shoots shorter than 5 cm bear a smaller proportion of mixed buds. Furthermore, the fruit set rate in short or medium shoots is significantly lower than that in longer shoots. The reduced shoot length coupled with the reduced proportion of mixed buds and fruit set lead to the rapid loss (2-3 years) of nut bearing capability in branches of hazel. This information is fundamental in order to drive horticultural management to obtain a correct equilibrium between vegetative and reproductive activity.

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Tables and figures

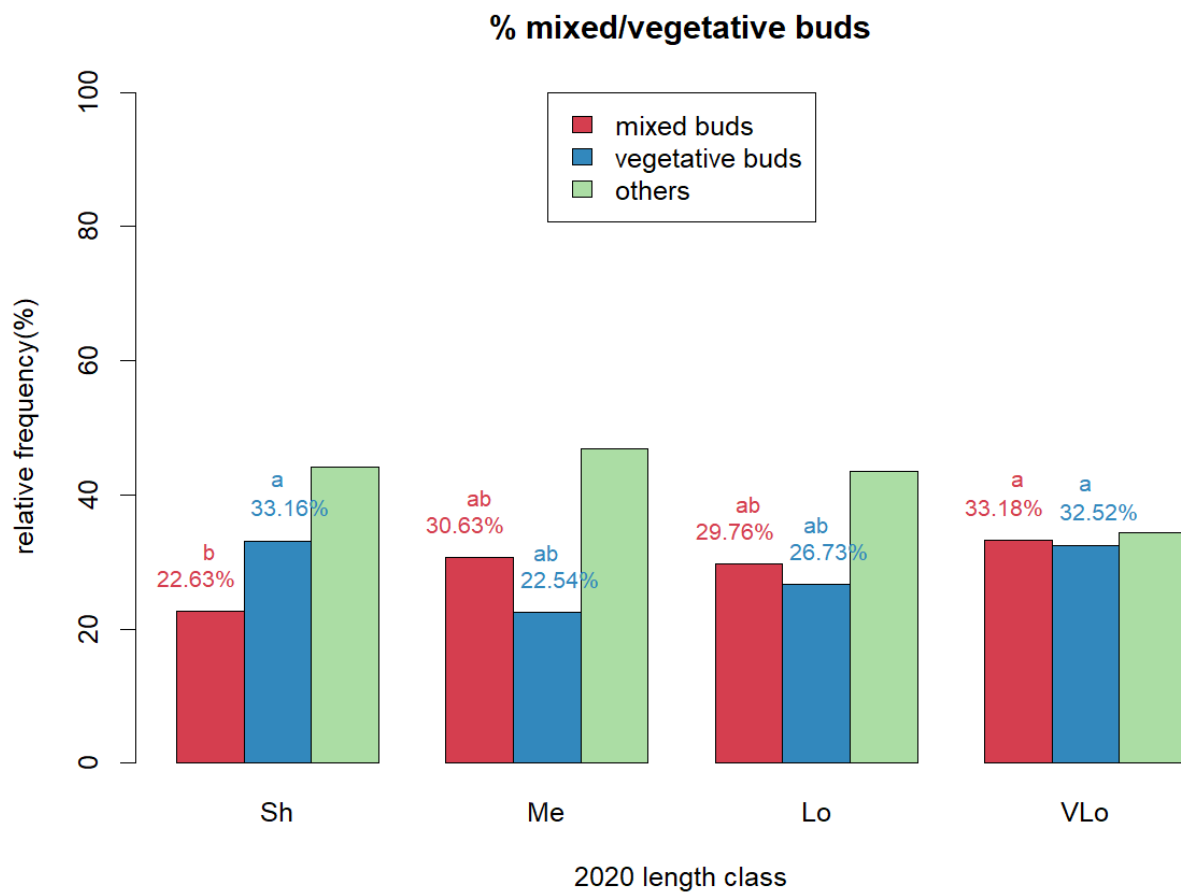


Fig.1: Percentage of mixed buds, vegetative buds, and others (catkin + blind nodes) for the different 2020 classes of length. Three proportion tests were used to test the difference of each bud's fate between parental classes. Proportions with different lower-case letters are significantly different at $P < 0.05$ (prop.test in RStudio).

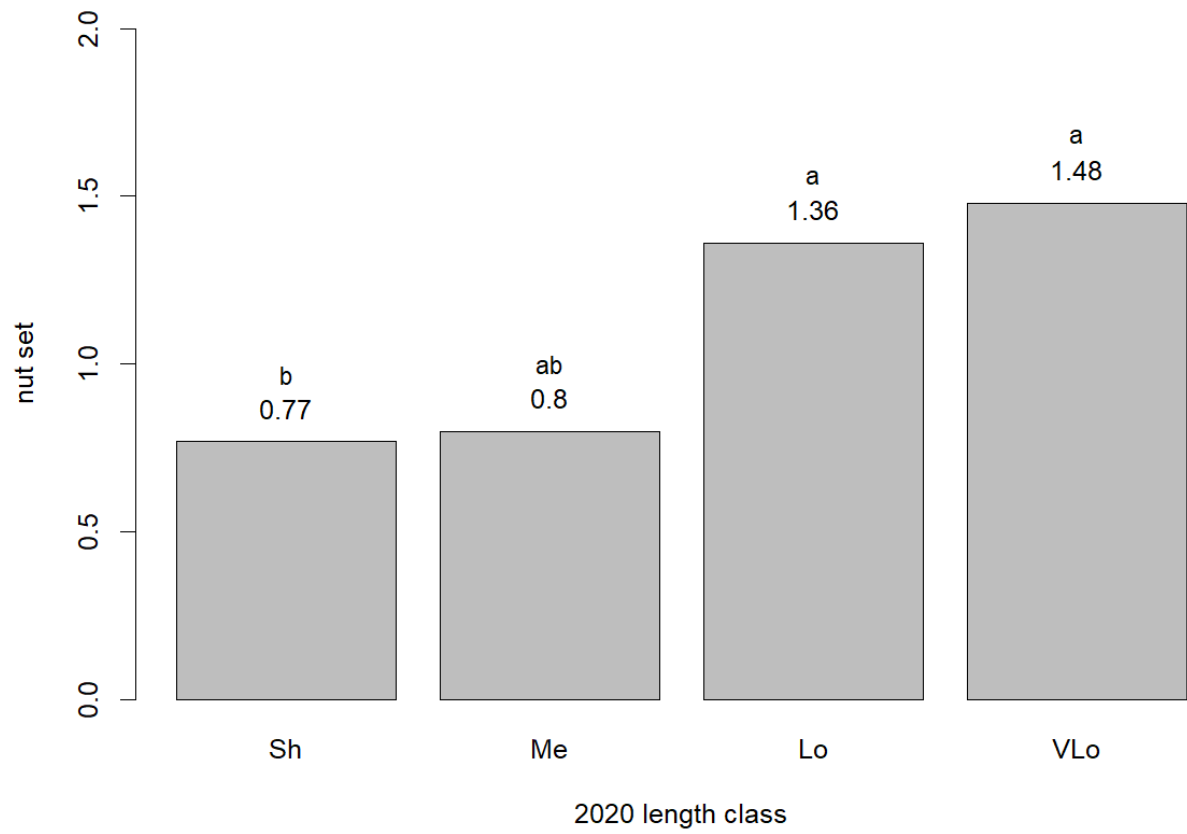


Fig.2: Fruit set (number of nuts/number of mixed buds) for the different 2020 classes of length. Means with different lower-case letters are significantly different at $P < 0.05$ (Tukey test in RStudio).

lateral 2021 shoot length(cm) ~ lateral 2020 shoot length(cm)

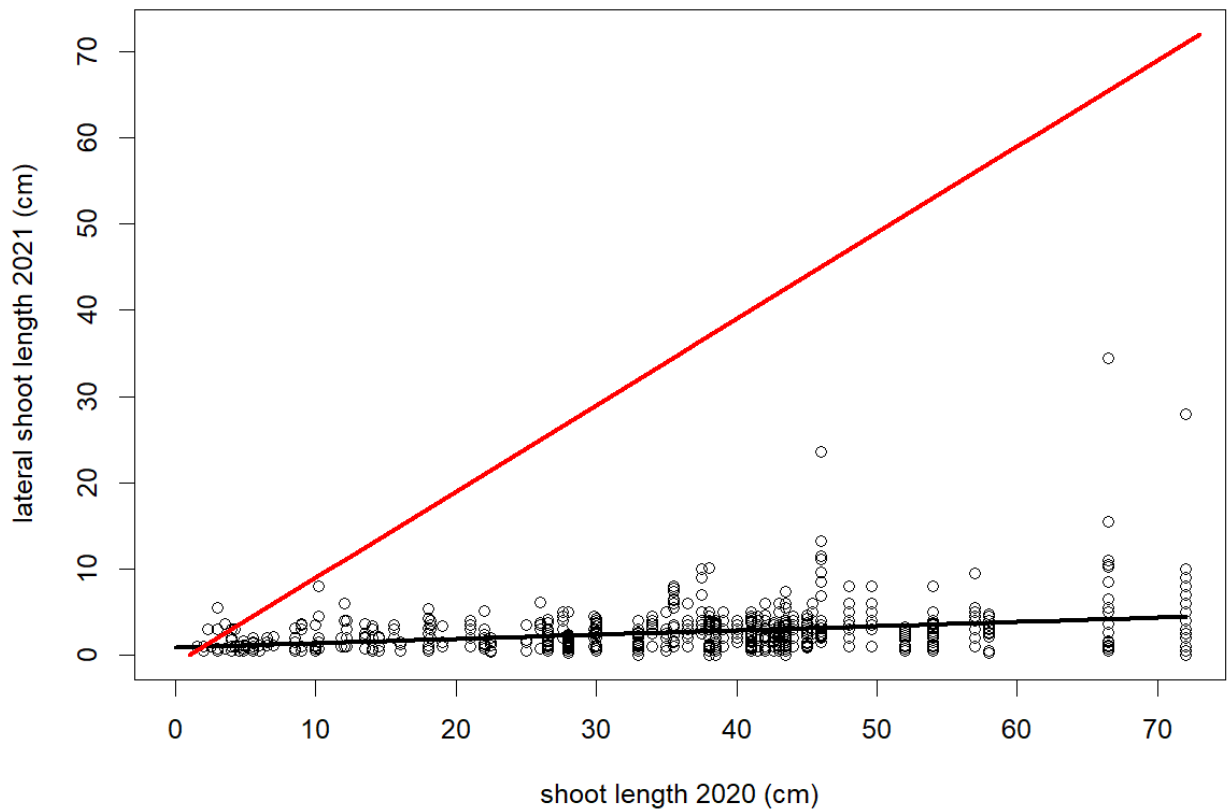


Fig.3 : Relationship between length (cm) of lateral 2021 shoots and length (cm) of shoot from 2020 (black line). $y = 1.39 + 0.04x$ ($R^2 = 0.06$, $P < 0.001$). The red line $y = 1 * x$ represents the linear relationship if the 2021 shoots were the same length as 2020 ones.

lateral child length from different class

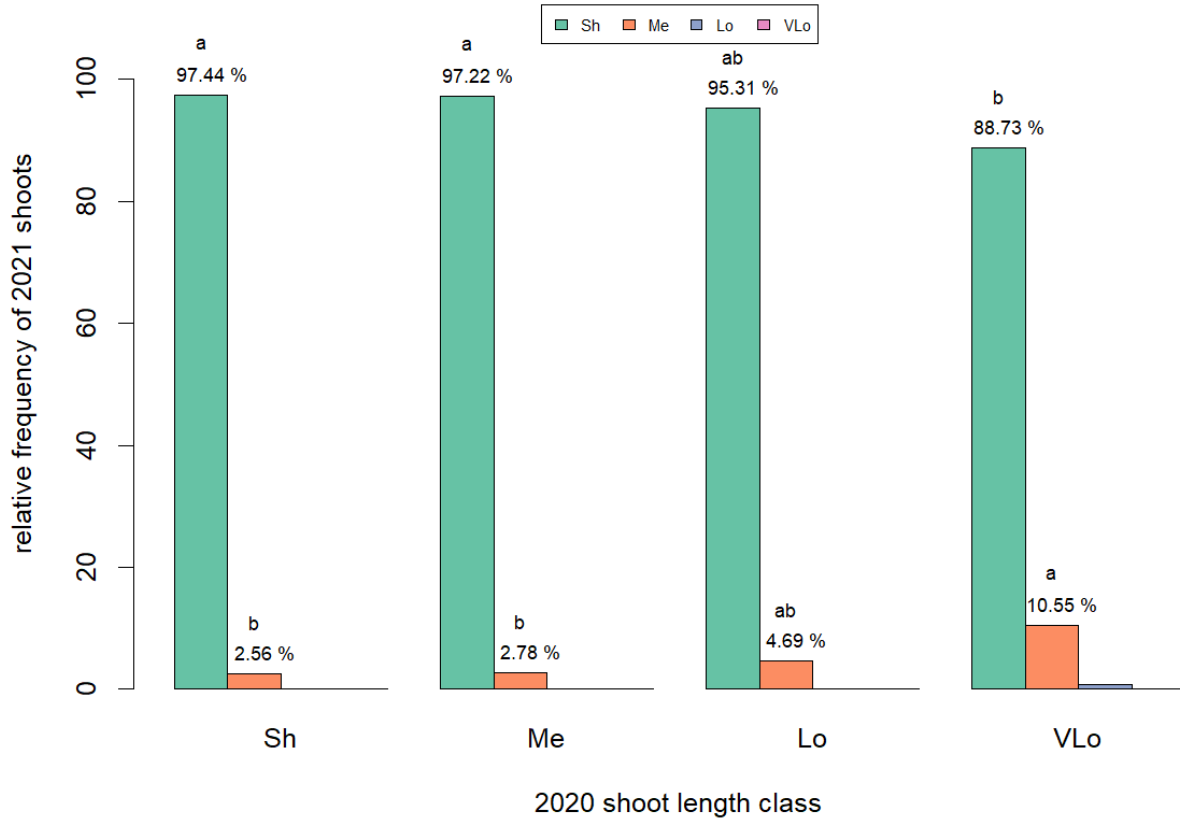


Fig.4 : Proportion of 2021 shoots (for each class length) per each class length of 2020 shoots. Two proportion tests were used to test the difference of 2021 1-year-old Sh shoots and Me shoots, respectively, between parental classes. Proportions with different lower-case letters are significantly different at $P < 0.05$ (prop.test in RStudio).