INFLUENCE OF FLORAL STRUCTURE AND FLOWER BUD QUALITY ON PRODUCTIVITY AND FRUIT SHAPE IN DIFFERENT APPLE CULTIVARS[1]

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ABSTRACT- This study examines the relationship between floral structure and bud quality with the productivity and fruit shape of Gala, Fuji and Daiane apple cultivars under the mild winter conditions in Southern Brazil. Six different types of floral structures were characterized in field growing plants, according to their nature and bud size: spurs, short and long twigs with weak and vigorous buds. Variables related to the phenology and the productivity for these different structures were evaluated. Gala and Fuji cvs. showed earlier phenological development in the twigs, and cv. Daiane in the spurs. For the three cvs. the highest percentage of buds in each phenological phase was observed in the long twigs. The long twigs also showed the highest sprout and fruit set index, floral number per cluster, and leaf area in the three cvs., while the bud abortion was higher in the spurs than in the twigs. No difference was observed among the structures in cvs. Gala and Fuji regarding to the fruit shape. In the cv. Daiane, however, a tendency to higher length diameter ratio of the fruits produced by the long twigs was observed.
Index terms: *Malus domestica*, floral structure, productivity, fruit shape.

INFLUÊNCIA DAS ESTRUTURAS FLORAIS E QUALIDADE DA GEMA FLORAL NA PRODUTIVIDADE E FORMATO DO FRUTO EM DIFERENTES CULTIVARES DE MACIEIRA

RESUMO - Este trabalho examina a relação entre a estrutura floral e a qualidade da gema com a produtividade e o formato do fruto, nas cultivares de maçã Gala, Fuji e Daiane sob condições de inverno ameno, no Sul do Brasil. Seis diferentes tipos de estruturas florais foram caracterizados em plantas crescendo em pomar, de acordo com sua natureza e tamanho da gema: esporões e brindilas curtas e longas com gemas fracas e vigorosas. Foram avaliadas variáveis relacionadas à fenologia e à produtividade nestas estruturas. As cultivares Gala e Fuji apresentaram desenvolvimento fenológico precoce nas brindilas, e a cultivar Daiane, nos esporões. Entretanto, nas três cultivares, a mais alta percentagem de gemas para cada uma das fases fenológicas foi encontrada nas brindilas longas. As brindilas longas também apresentaram as mais altas taxas de brotação e de pegamento do fruto, maior número de flores por cacho, e maior área floral para as três cultivares, enquanto a taxa de abortamento de gemas foi maior para os esporões do que para as brindilas. Nenhuma diferença foi observada entre as estruturas florais nas cultivares Gala e Fuji relacionada ao formato do fruto. Na cultivar Daiane, entretanto, foi observada uma tendência de frutos com maior razão comprimento diâmetro, em frutos produzidos pelas brindilas longas.
Termos para Indexação: *Malus domestica*, estruturas florais, produtividade, forma do fruto.

INTRODUCTION

The increase in the apple market in Brazil creates the need for improvement in fruit quality. The consumers' requirement for a better product reflects in the agro-industrial sector, with a high standard that requires discarding 30% of the apple production. For this reason, it is necessary to develop orchards with higher productivity of fruits and more suitable products to market needs using simpler techniques and low costs for the producers (WOSIACKI et al., 2004). To achieve this goal, it is necessary to know the apple fruiting process, and this knowledge requires the understanding of the floral biology.

Apple trees (*Malus domestica* Borkh.) have vigorous growth and variation in floral structures. This characteristic may lead to an uneven quality and, consequently, variable profits for producers (RODRÍGUEZ**;** RODRÍGUEZ, 1997).

Several studies have been carried out to evaluate the influence of the flowering structure on the production and quality of fruit. Differences re-

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lated to the flowering structures have been indicated as the cause for variability in fruit quality. Iuchi (1987) noticed that the phenological variation is an important component in fruit size, since fruits from buds that have an earlier burst could receive a major amount of nutrients and photosynthates. The size of the fruit would be regulated by the number of days in the development period from full bloom to harvest (OLSEN**;** MARTIN, 1980).

The leaf area is considered one of the most important components of the fruiting structures. It influences fruit size and quality because branches with a larger leaf area have a higher photosynthetic capacity, reducing the competition for photosynthates with other branches (COSTES, 2003; NACHTIGAL, 2000). The chemical composition of branches (carbohydrates, phytohormones, and nutritional status) can also influence fruit quality. Likewise, the position of the fruiting structure within the canopy is important for fruit development (ROM & BARRIT, 1987).

The quality of flowers, which is related to the amount of accumulated chill, is also a very important characteristic influencing fruit quality (OUKABLI et al., 2003), as well the characteristics of the flowering structure such as diameter, length, age and leaf area. The number of flowers is important for fruit set. This characteristic is related to the length and age of the branch. Fruit set is influenced by the position of the inflorescence in the canopy, affecting the vegetative development and, finally, the inflorescence growth (NACHTIGALL, 2000).

Some authors have considered the influence of bud size on fruit set and quality saying that the potential of the bud can be evaluated by its size, because when the size increases, there is an improvement in the fruit set (ROM**;** BARRIT, 1987; NACHTIGAL, 2000).

The objective of this study was to evaluate the possible influence of flowering structures and bud size on the production and fruit shape of three apple cultivars: Gala, Fuji and Daiane.

MATERIAL AND METHODS

This study was carried out at the Estação Experimental de Caçador (26°49'07"S 50°59'06"W) of Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), Brazil (26°49'07"S, 50°59'06"W). During the dormancy period, in September 2006, 20 nine-year-old trees were selected for each cultivar, and six different fruiting structures were characterized on those trees, with respect to branch and bud sizes: 1- spur (< 10 cm) of weak bud (< 3.5 mm of diameter); 2- spur of vigorous bud (> 4.5 mm of diameter); 3- short twig of terminal growth (<30 cm) of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth (>30 cm) of weak bud; 6- long twig of terminal growth of vigorous bud. Five buds of each structure per tree were sampled.

The phenological development was observed until fruit set and characterized according to Fleckinger (1953). Sprout index, abortion and fruit set were calculated as percentage of the total sampled buds. The leaf area was measured from all the leaves in each bud with a leaf area meter. The fruit shape was characterized by the length/diameter ratio, as measured with a digital pachymeter .Data were processed by ANOVA and means were compared by Duncan test at 5% error probability.

RESULTS

Phenological evaluation

The mean dates for the beginning of each phenological phase were earlier in the long twigs in Fuji and Gala cultivars. However, in the cv. Daiane, buds on spurs started developing earlier than those on twigs (data not shown). Despite this fact, the long twigs showed the highest percentage of sprouting buds for each phenological phase in the long twigs for all three cultivars.

The cv. Gala (Fig.1) showed a high difference in percentage of buds for each phenological stage for the different structures. In the long twigs with vigorous buds, 87% of the floral buds achieved the C3 stage (sprout), and in the spurs of weak buds only 19% achieved this stage. For cvs. Fuji and Daiane, the difference between the percentages of buds in the floral structures was smaller than in the cv. Gala. 'Fuji' (Fig. 2) showed a high percentage of buds in C3 stage, and an accentuated decrease in D2 stage (flowering), indicating a high percentage of vegetative buds. In 'Daiane' (Fig.3), a high percentage of buds in C3 stage could be observed. Only the spurs showed a high drop between C3 and D2 stages. But the most conspicuous aspect of the phenological development in this cultivar is the great difference between the percentages of buds in C3 stage and I (fruit set). This fact could be attributed to pollination problems in the experimental area.

The sprout index (Fig. 4) was higher for all cultivars on the long twigs and lower for the spurs of weak buds. 'Gala' showed statistical differences between the percentages of sprout in all the floral structures, with a continuous decrease from the long

twigs to the spurs. This cultivar also showed the lowest sprout index for all the different floral structures. For 'Fuji', the highest sprout index was observed on the long twigs (92%) while the spurs of weak buds showed a sprout index of 52%. For cv. Daiane, a smaller difference between the different structures was observed; only the spurs with weak buds showed statistical difference from the other floral organs.

Fruit set data (Fig. 5) showed the highest percentage on long twigs, and the lowest on spurs. For cv. Gala the long twigs of vigorous spurs showed the highest fruit set of all three cultivars (49%)**,** but the disparity between the floral organs was higher than that found in the other cultivars. For cvs. Fuji and Daiane the long twigs did not show a percentage of fruit set as high as in cv. Gala, but the difference between the structures was less evident than that observed for that cultivar.

Productivity and fruit shape evaluation

The leaf area/number of leaves ratio (Table 1) was higher in all cultivars for the long twigs with vigorous buds, and lower for the spurs. The difference in leaf area between the structures (data not shown) was particularly great in the cv. Fuji, in which the leaf area of the long twig of vigorous buds increased 10-fold compared to the spur of weak buds. A pattern could not be observed between bud size and leaf area. It seems that leaf area is more closely related to the structure where it is originated than to bud size.

The number of flowers per cluster (Fig.6) was higher in the long twigs and lower in the spurs. In cv. Gala a continuous decrease was observed from the long twigs to the spurs. The cv. Fuji had a lower number of flowers per cluster than the other cultivars. 'Daiane' presented the highest number of flowers per cluster, with almost five flowers per cluster in the long twigs. However, this cultivar showed the lowest fruit set.

Regarding to the bud abortion (Fig. 7), results were the opposite from what was observed on the other variables. For all cultivars, the highest rate of bud abortion was observed on spurs, and the lowest on long twigs. On the sample buds of cv. Daiane, bud abortion was not observed on long twigs of vigorous buds. The rate was low even on the spurs (less than 10%). On the other hand, cv. Fuji showed a high abortion rate, especially in the spurs of weak buds, which had a rate of 38%.

Regarding to the fruit shape (Table 2), no statistical differences were observed between the floral organs. However, for cv. Daiane, a tendency of the spurs to develop flattened fruits could be noticed. Cultivar 'Daiane' also showed the highest length/diameter ratio or the development of more elongated fruits in this cultivar. Cultivar 'Fuji' showed the lowest length/diameter ratio, or the more flattened fruits.

DISCUSSION

Phenological evaluation

Data from phenological evaluation showed anticipation in development for the long twigs on cvs. Fuji and Gala. These data is contradictory with current literature. Kozma et al. (2003), reviewing the factors that affect apple's phenology, stated that bud position in the plant is very important for its phenological development. These same authors say that old spurs would produce floral organs with the earliest phenological development, followed by young spurs, and then by terminal buds of long twigs. An important fact that must be considered is that data from Kozma et al. (2003) were obtained in cold climate regions, different from the mild climate region where this study was carried out. The data from this study is important for showing that these are differences that could be attributed to the climatic conditions for plant growings.

Productivity and fruit shape evaluation

Regarding to the ratio of leaf area to number of leaves, authors such as Lauri and Kelner (2001) reported that short twigs show a better leaf area/twig ratio, while Sansavini and Coreli-Grapadelli (1992) emphasize that there is an advantage in performing pruning to maintain a canopy rich in spurs and with good light penetration. However, this again was observed in cold climate regions. According to the present study, the highest leaf area/number of leaves ratio was found on the long twigs, and the lowest on the spurs. It has already been observed, under mild climate regions, that the spurs are less numerous and develop smaller leaves and that there is a decrease in the total leaf area of fruiting structure**s**, contributing to the development of smaller fruits (PETRI et al., 2006; PETRI**;** LEITE, 2004).

The number of flowers per cluster was higher in long twigs than in the spurs. Nachtigal (2000) had already observed this fact for cv. Fuji, but not for 'Gala', as it was observed in this study. Racksó and Miller (2010) say that the number of flowers per cluster is an important feature and clusters with few flowers rarely set fruits. This relationship between a higher numbers of flowers per cluster with fruit set was observed in this study, with long twigs showing better results for both parameters.

According to Iuchi (1987) the number of days between blooming and fruit set is important.

The later the blooming, more competition will exist between the developing fruits and the shoots. However, this fact was not confirmed in this study. It was observed that the spurs from cv. Daiane started their development earlier than the long twigs and still had lower fruit set. The author says that twigs would have a higher fruit set than the spurs because the former have a major nutritional content, avoiding competition between fruits and shoots. The low amount of nutrients in the spurs could be suggested as the cause of the high rate of bud abortion in these structures, which was also observed in the present study.

Fruit shape, expressed by the length/diameter (L/D) ratio, showed no statistical differences among the structures in the different cultivars. Nachtigall (2000) found no difference in the fruit shape in the cv. Gala, but noticed that, fruits from the long twigs had a higher L / D ratio in the cv. Fuji. Petri (1983) evaluating several climatic conditions across the state of Santa Catarina, noticed a tendency of long twigs to produce more elongated fruits in the cvs. Gala, Fuji and Golden Delicious. From the three cultivars 'Daiane' developed more elongated fruits, while cv. Fuji showed more flattened ones, with a mean L/D ratio of 0.87. Petri and Leite, (2004) reported that fruits from spurs in cv. Fuji were very flattened, with a minimum mean L/D ratio of 0.71, whereas the normal for this cultivar is close to 1.0. The results of this study could be justified by the high number of accumulated chilling hours in the winter season, when the experiment was carried out. In cases like this, it has been observed that the shape of fruits formed on different structures shows no variation.

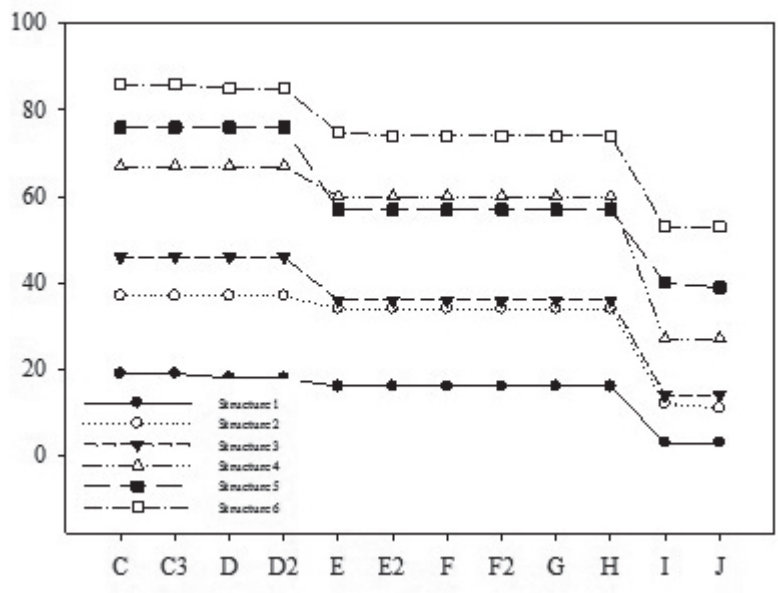

FIGURE 1- Sprouting buds (%) for each phenological phase in different flower structures in Gala cultivar. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador-SC, Brazil.

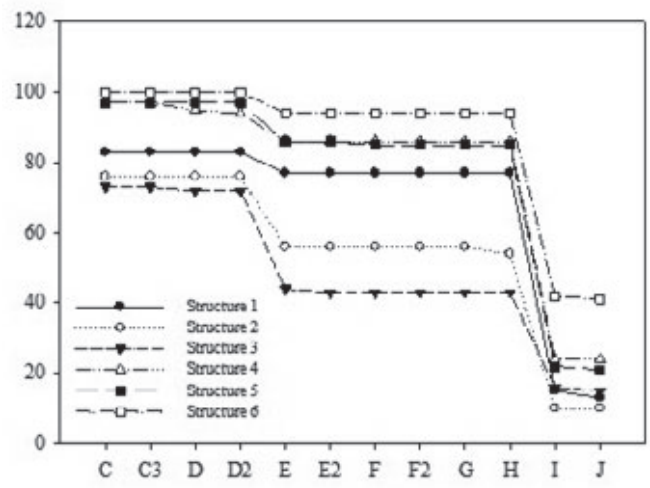

FIGURE 2- Sprouting buds (%) for each phenological phase in different flower structures in Daiane cultivar. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador-SC, Brazil.

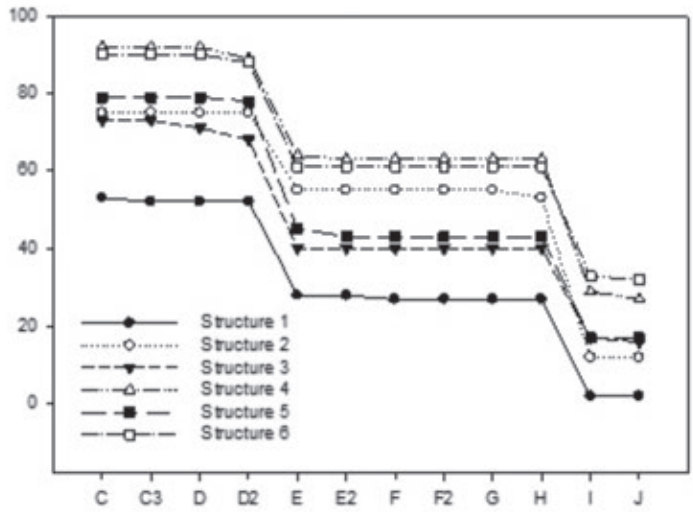

FIGURE 3 - Sprouting buds (%) for each phenological phase in different flower structures in Fuji cultivar. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador-SC, Brazil.

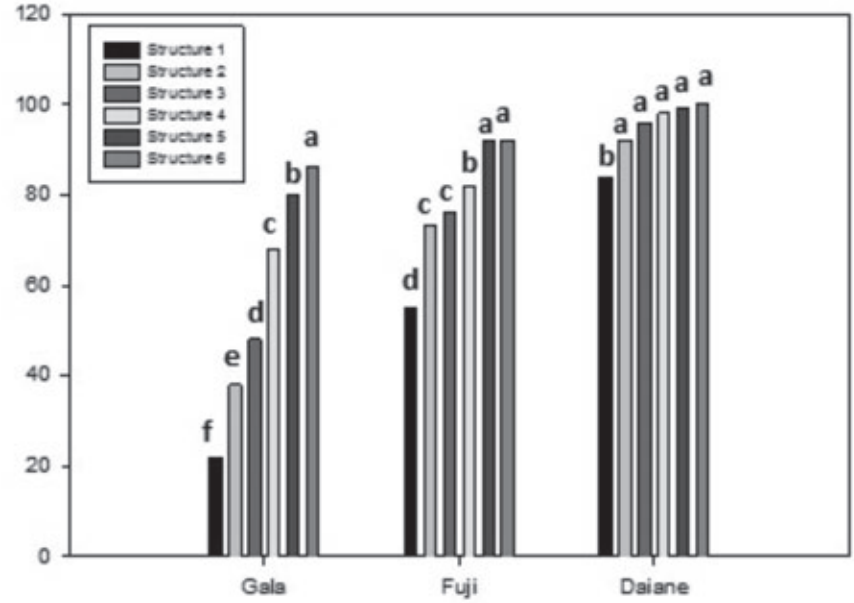

FIGURE 4- Sprout index (%) of different fruiting structures of three apple cultivars. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador-SC, Brazil.

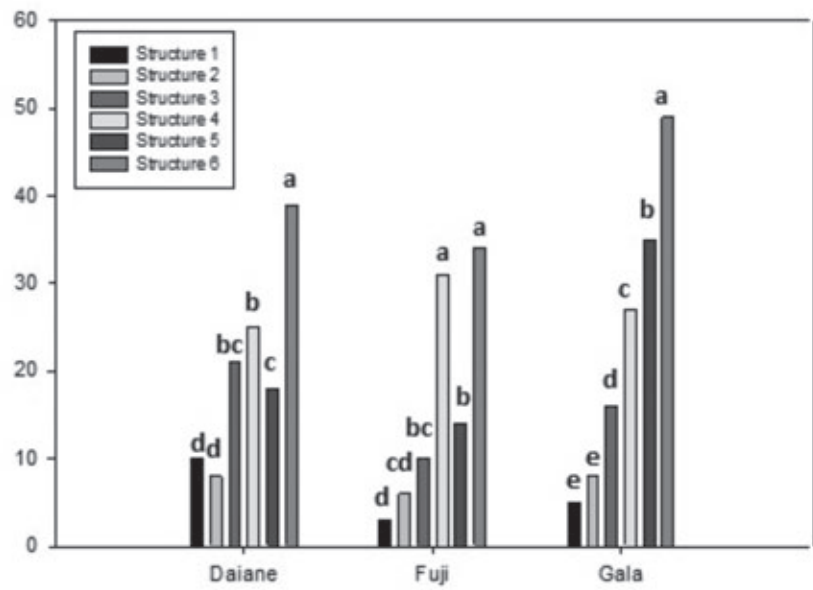

FIGURE 5- Fruit set (%) of different fruiting structures of three apple cultivars. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador-SC.

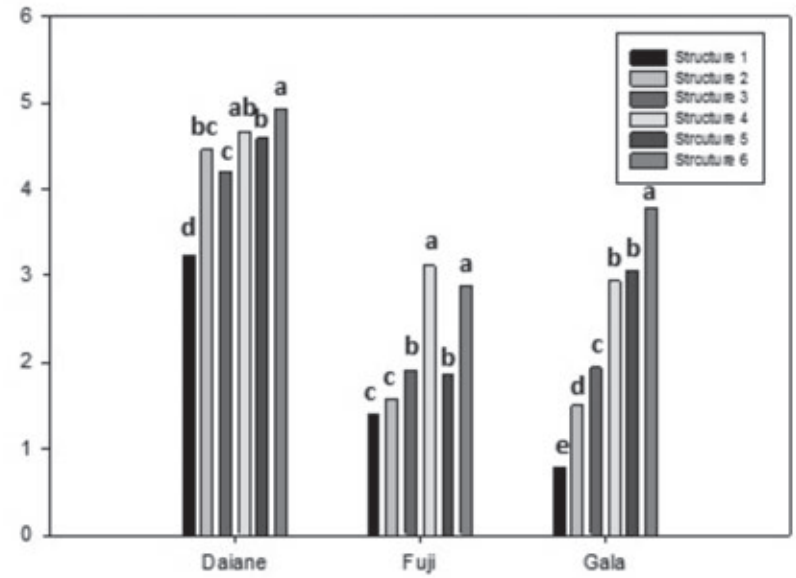

FIGURE 6 - Number of flowers per cluster in different fruiting structures of three apple cultivars. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador, SC, Brazil, 2007.

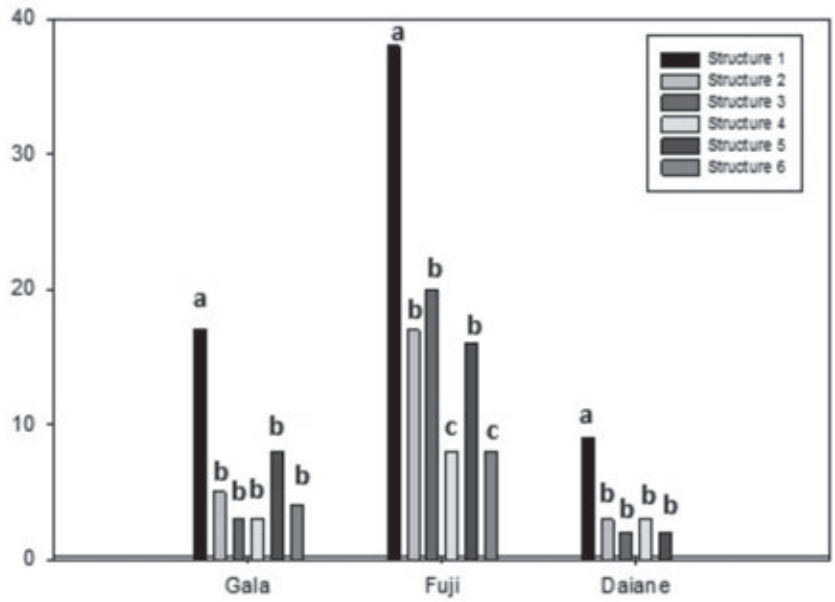

FIGURE 7- Bud abortion rate (%) of different fruiting structures of three apple cultivars. Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador, SC, Brazil, 2007.

TABLE 1- Leaf area/number of leaves ratio in different fruiting structures of three apple cultivars.

Structure	Leaf area / Number of leaves ratio		
	Gala	**Fuji**	**Daiane**
1	11.75 **c**	10.35 **d**	16.17 **d**
2	11.51 **c**	13.19 **c**	18.18 **c**
3	11.75 **c**	19.36 **b**	21.11 **b**
4	16.35 **b**	20.17 **b**	22.57 **b**
5	27.25 **a**	23.88 **a**	22.69 **b**
6	27.47 **a**	24.64 **a**	24.87 **a**
CV (%)	8.79	6.96	5.86

Means followed by the same letter in columns are not significantly different according to Duncan's Multiple Range Test (P < 0.05). Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador, SC, Brazil, 2007.

TABLE 2- Fruit shape in different fruiting structures of three apple cultivars

Structure	L/D ratio		
	Gala	Fuji	Daiane
1	0.947 **a**	0.884 **a**	1.016 **ab**
2	0.953 **a**	0.852 **a**	0.947 **b**
3	0.944 **a**	0.838 **a**	1.014 **ab**
4	0.959 **a**	0.879 **a**	1.063 **a**
5	0.999 **a**	0.892 **a**	1.064 **a**
6	0.984 **a**	0.915 **a**	1.064 **a**
CV(%)	7.07	10.65	7.42

Means followed by the same letter in columns are not significantly different according to Duncan's Multiple Range Test (P < 0.05). Structures: 1- spur of weak bud; 2- spur of vigorous bud; 3- short twig of terminal growth of weak bud; 4- short twig of terminal growth of vigorous bud; 5- long twig of terminal growth of weak bud; 6- long twig of terminal growth of vigorous bud. Caçador, SC, Brazil, 2007.

CONCLUSION

Based on the results, it can be concluded that, in mild climate regions of Southern Brazil, long twigs show a higher productivity compared to spurs, regarding to leaf area, number of flowers and especially the percentage of fruit set. Thus, it is convenient, during the pruning process, to maintain a high number of long twigs with terminal buds.

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