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Full Length Research Paper

Investigation of branch breaking resistances in "Sari Zeybek" fig cultivar

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The aim of this study was to examine the branch breaking characteristics of the 4 to 5 years old branches mechanically by a determination of the breaking resistance in Sari Zeybek fig cultivars. In this respect, the study was conducted with 10 different ages for trees belonging to Sarilop cultivar, known with a characteristic of drying and Sari Zeybek cultivar, known with equal or even better characteristics. The sclerenchyma tissues of the 1 to 5 aged branches of Sari Zeybek cultivar were weaker in degree than some other fruit tree species, especially the Sarilop cultivar. Furthermore, it was brought out that the breakages were related to the flexibility of tissues even with the excess forced application (150 kg.) in Sarilop. In Sari Zeybek cultivar, where there is an existence of the branch breakage problem, the length and diameters of branches increased with the increasing branch ages. In particular, the forces at the branch collar were increased due to the fruit weight increase in trees, starting with the 4 to 5 year aged branches. According to the approach of encouragement of branch breakages due to the aforementioned reason, it was taken seriously that shape prunings need to be made more carefully, and not allowed in over critical levels branch lengths and angles within 1 to 4 years growth in Sari Zeybek cultivar.

Key words: Sari Zeybek, fig, branch breakage.

INTRODUCTION

Fig, as a subtropical fruit, has a wide ecological adaptation capacity. Being widespread in all regions of Turkey, it has been grown intensely in a wide area through Big and Small Meander basins of the Aegean region. Approximately, 75% of the fresh fig production and almost all the dried figs subjected to exports are grown in these river basins. The compatibility of regional ecological conditions enabled the most qualified figs to be grown only in this river basin (Aksoy, 1990).

Turkey supplies more than half of the world's fresh fig and dried fig yields. Sixty-five percent of the fig's yield in Turkey takes place in Aydin. Aydin is in the first place of Turkish fig production as a result of its quality and superior capacity. There are 6.4 million fig trees in Aydin.

The amount of fresh figs obtained from these trees ranges between 140,000 and 170,000 tons and about 90% of this amount is processed as dried fig. In 2004, about 186,000 tons of fresh figs were produced (Köksal and Güneş, 2005).

When the commercial fig cultivation is in question, the clone choice is crucial. The best standard clones for drying are Sarilop and Sari Zeybek. The trees of Sari Zeybek clone are 7 to 8 m high and 8 to 9 m wide, and they form fastigiated-broad branches in young ages, while they get flaccid as they grow older. Although, the breba fruits cannot be fertilized, the main crop fruits are the very important yields and should be fertilized absolutely. The average fruit weight is 65 g and the fruit diameter is 55 mm. The first maturation takes place at the end of July and at the beginning of August, whereas the harvesting period lasted 40 to 45 days. This clone is a good quality of the table fig and is of high quality for the standard dried fig. In recent years, fresh fig consumption

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and export show an increase (Aksoy and Şahin, 2001).

Several investigations have been performed on xylem and cortex anatomy in various plant species. When related with tissue resistance, the importance of sclerenchymatic structures is addressed. In plants, a supportive tissue is formed against the mechanical factors from the external environment. The supportive tissue is divided into two parts as collenchyma and sclerenchyma. While collenchyma is formed by cellulose walled viable cells, sclerenchyma tissue walls are composed of dead lignin cells. These tissue cells are found in the regions where they have completed their development. They may be in the form of petrosal cells, sclerits, or sclerenchymatic fibers. The term fiber is used for long and narrow xylem and cortex cells other than streaks and parenchyma. The fibers belonging to sclerenchyma (sclerous tissue) are found in many organs of the plants. They are generally located in stem, leaves, and in the centre of peripheral roots. Fibers are divided into two: xylem and cortex fibers (Özörgücü et al., 1991). It is determined by researchers that these schlerancymatic structures for rooting of cuttings and stage of formation graft union in many fruit species have become generally problematic (Tekintaş, 1988; Balta, 1989; Balta and Şen, 1998).

The aim of this research was to examine the branch breaking characteristics of the 4 to 5 years old branches mechanically, by determination of the breaking resistance in Sari Zeybek cultivars of fig. In this respect, the study was conducted with 10 different ages of trees belonging to the Sarilop cultivar, known with the characteristic of drying and Sari Zeybek cultivar, also known with equal or even better characteristics.

MATERIALS AND METHODS

This study was carried out at Adnan Menderes University (Department of Horticulture, Faculty of Agriculture) and Erbeyli Fig Research Institute between 2002 and 2004. The plant material used comprised 10 different ages of trees among Sari Zeybek and Sarilop clones taken from the fig collection garden at Erbeyli Fig Research Institute. Sarilop clone is the most prominent dried variety which originates and spreads to the Aegean region. The growth rate is mid-fastigiated and has a broad and sparsely branched structure. At harvest, the fruit stalk remains on the branch of this clone are sweet, aromatic, and are easily peeled cover. It is a standard dried fig besides a good quality for table use. This clone with high fruit set ratio ripens between the end of July and the end of September. Sari Zeybek originates from Erbeyli and spreads through the Aegean region. It grows with fast, dense and fastigiated branches. In addition to having an easily peeled cover, this dried variety has also been used as a table fig. The ripening takes place between the end of August and the end of September.

Sari Zeybek has superior characteristics related with fresh (table) and dried fig quality, while Sarilop clone has some advantages as it quickly becomes ripe. In total, the most important problem is intensely observed in branch breaking after 4 to 5 years.

In this respect, evaluations directed to determine the causes of branch breaking in Sari Zeybek fig cultivar necessitated an investigation of whether or not there is a significant difference between the breaking resistances of same aged offshoots in the Sarilop fig cultivar. In this direction, on thirteen trees used in the experiment, the investigation was performed on the structure connected to the main stem at the beginning, middle and end of the vegetation. However, the breaking resistance measurements, depending on the affective loads on branch breaking encountered in Sari Zeybek fig cultivar, were performed on the harvest period (August 19, 2004) when leaf, branch and fruit load was highest. In this setting, trees selected among Sarilop and Sari Zeybek cultivars were compared for breaking resistances using identical moment exerted on the main branches with similar branch angles and branch diameters. This procedure has been performed according to random parcels experimental patterns choosing a couple of main branches on 13 trees, of which 10 were old and each was taken on repetition. On these main branches selected on each repetition, a total of 48 branches in six different age groups (15 in four ages, 12 in five ages, 7 in six ages, 6 in seven ages, 4 in eight ages and 4 in nine ages), whose numbers varied depending on whether they were on the main branch or not, were studied. Before the resistances were measured, total branch length, branch diameter and branch angle had been recorded. In angle measurements, the angle between the stem and branch were considered. Breaking resistance measurement was carried out by means of a dynamometer with a capacity of 150 kg. Dynamometer was fixed on the measured branch and force was exerted until breaking was observed. The resistance value at the time of breaking was recorded through the scale of dynamometer. After breaking, the branch mass was weighed. In order to calculate the breaking moments, the distance between the point where the dynamometer was connected to the branch and the branch connection point where breaking was observed was measured and this value was multiplied by the sum of 'breaking resistance' and 'branch mass'. Also, fresh and dried (at 40°C until the weights were constant) weight, volume and density measurements on three branches, randomly selected from both two cultivars between one and five years, were performed.

In accordance with the random parcels experimental design, correlation-regression and variance analyses were carried out using TARIST statistical program. The effective components of variation were found out by the principal component analysis using SPSS program. Correlation matrix was principally calculated using standard data for this analysis. In order to find the most important one among all parameters studied in this study, PCA was used. On PCA, 'eigenvector' value was calculated to determine the contribution of each parameter on the variation of breaking moments for Sari Zeybek fig cultivar.

RESULTS AND DISCUSSION

Breaking resistance measurements were performed on the harvest period (19.08.2004) when leaf, branch and fruit load was the most active in order to determine the physical effects of branches on branch breaking in Sari Zeybek cultivar. Before the resistance measurements on branches, total branch length, branch diameter and angle measurements were performed.

Following the statistical evaluations of the obtained data, variance analysis results between branch age and breaking moments are given as a whole in Table 1. As seen in Table 1, there is a significantly positive relation at alpha level of 1% between breaking moments and ages of broken branches. While the branch age increased, the breaking moments also increased. Also, it is observed that the breaking moments of 4 to 5 aged branches are less than 6 to 7 and 8 to 9 aged branches (Table 2).

Table 1. Variance analysis table between breaking moments and branch age.

Source of variance	Degree of freedom	Sum of squares	Mean of squares	F
Age groups	2	7539.434	3769.717	10.512**
Error	45	16137.950	358.621	
Total	47	23677.384	503.774	

ns = not significant, * = significant at alpha level 5%, ** = significant at alpha level 1%.

Table 2. Relation between breaking moments and branch age.

Age group (Age)	Breaking moment*
8-9	47.278[a]
6-7	25.352[b]
4-5	8.172[c]

*: Significant at alpha level 5%, LSD =12.725

These findings are concordant with the observations that branch breaking problem in Sari Zeybek fig cultivar occurred when trees are 4 to 5 years old.

When the branch age is considered as the principal factor, it is observed that parameters except for branch angle variations (diameter, total length and breaking moment) increased parallel to the increasing branch age and are statistically important. Since this was related with the expected results, depending on the increased age, we did not enclose variance analysis tables on these relations. Results related with the correlations of the considered parameters are given in Table 3, as it is thought that they may be effective on branch breaking.

As it may be observed in Table 3, there is an important statistical relation at a 1% level between breaking moment and parameters, like total branch length, branch diameter and branch age. In other words, breaking moments increase in a positive direction with the increases in total branch length, branch diameter and branch age. Likely, this correlation is also found between branch age and two parameters: total branch length and branch diameter at 1% level. Total branch length and diameter increases are expected as a natural result of vegetative growth due to branch age, while the increase in breaking moments does not support the hypothesis that breaking occurs after 4 to 5 years, when trees generally begin to fructify. However, with another point of view, it should be considered that the load on the branch by the increasing branch age, length and diameter is reflected on the branch owing to the lengthening level arm (branch length) and the required force for breaking is more easily reached.

In this study, as stated in the method, forces affecting the branch collar are calculated as breaking moments. Since the force affecting the branch collar is given as the value obtained through multiplication of branch load and total branch mass with level arm, it means that force affecting branch collar increases as the branch length increases. In other words, while the branch lengths grow longer and the level arm extends, breaking moments increase; that is, fruit load on long branches exerts a greater force on the branch collar.

Branch breaking in Sari Zeybek fig cultivar that causes important damage occurs through the variation in branch breaking resistances and has a variation between the 4 and 9 year aged branches. Principal component analysis is applied on some parameters considered in the experiments, such as total branch length, branch angle, branch diameter and branch age that form this variation in order to demonstrate their efficacy in breaking resistances. Eigenvalues, eigenvector values and % variation values calculated by the first two components, related with this analysis, are given in Table 4.

As it was observed in Table 4, in order to determine the most important character among the six characters [total length (cm), diameter (mm), branch mass (kg), branch age, initial branch length (cm) and angle] that create the variation in breaking moments, PCA analysis was carried out on the measurements for diverse aged branches of Sari Zeybek fig cultivar by exerting different forces. The first two principal components consist of 88.533% of the total variance of all characters and they show the highest correlation among the characters analyzed. Changes in total length and diameter explain 88.533% of the general variance, whereas other components form a small percent (only 11.467%) of the total variance.

Analysis of the eigenvector values provides information about the responsible factor for the discrimination of factors throughout the first two components. PC1 or the first component has 71.589% of the total variance. Total length (cm), branch diameter (mm), branch mass (kg), branch age and initial branch length (cm) have positive contributions on the first component. In other words, the parameters mentioned for the first component have a part in the formation of variation in terms of breaking moment values. Depending on the differences of parameters, this condition originates from the total length and branch diameter. Although, the angle value has a negative effect on the formation of variation; PC2 or the second main component formed 16.944% of the total variation. Since it was both observed in the variation and PCA analyses that the most effective parameter on the variation of breaking moments was the total branch length, regression equation between breaking moment and branch length was calculated and the related graph is presented

Table 3. Correlations for branch age, angle, diameter, total branch length and breaking moments' parameters.

Parameter	Breaking moment	Branch angle	Total branch length	Branch diameter
Branch age	0.736**	-0.110	0.846**	0.871**
Breaking moment	1.000	-0.076	0.862**	0.848**
Branch angle	-0.076	1.000	-0.069	-0.053
Total branch length	0.862**	-0.069	1.000	0.957**

**: Significant at alpha level 5%

Table 4. Eigenvalues, eigenvector values and % variation values calculated by the first two components on principal component analysis performed on the measurement data of Sari Zeybek fig cultivar branches broken by different breaking moments in different ages.

Parameter	Principal component	
	1	2
Total length (cm)	0.971	-0.003567
Diameter (mm)	0.966	-0.005310
Branch mass (kg)	0.910	-0.02309
Age	0.908	-0.05739
Initial branch length (cm)	0.872	0.159
Angle	-0.07463	.994
Eigen value	4,295	1,017
Variation (%)	71,589	16,944
Cumulative variation (%)	71,589	88,533

Extraction method: Principal component analysis. 2 components extracted.

in Figure 1, by means of regression analysis in Excel program for Microsoft Office. The mean breaking moments determined in various age groups of branches were evaluated by regression equation, and the critical branch lengths were calculated with 86% accuracy. According to this, it can be predicted that growing more than 122.86 cm from the main stem in 4 to 5 aged branches, 212.70 cm in 6 to 7 aged branches and 287.72 cm in 8 to 9 aged branches exceeded the critical breaking moments and caused branch breaking at the sites where branches communicate with the main stem. These evaluations contribute to the information of how long the branch lengths should be left during the corrective and yield pruning.

Breaking resistances on a total of 48 branches (ages ranged between 4 and 9), in Sarilop fig cultivar, was also performed in the harvest period (August 19, 2004) in order to find out the physical characteristics related with branch breaking. Before beginning the resistance measurements, the total branch length, branch diameter, and angle measurements were done. In angle measurements, the angle between the branch and its communicating stem was considered.

In Sarilop cultivar, force exertions were performed by a dynamometer as stated in the study's methods to find out the breaking moments. However, it was observed that none of the branches in four to nine aged groups were broken by a 150 kg dynamometer. Therefore, breaking moments of 4 to 9 aged Sarilop branches could not be calculated and since the breaking forces were over 150 kg, they were referred to as such. The elasticity of Sarilop clones and their resistance to 150 kg force made their comparison with breaking moments of different age groups insignificant. The most significant approach that explains breaking branches is the way that lower force exertions on branch collars, in early ages, grow increasingly in older ages. Since it is observed that the anatomical developments are not effective to increase breaking resistances by age, it should be thought that biochemical developments, particularly lignification, should take an important place on the basis of this problem. Density measurements by age groups were performed in Sari Zeybek cultivar, whose branches were easily broken at the 4 to 5 year aged branch, and in Sarilop cultivar, with no branch breaking problem. However, the results are given in Tables 5 and 6 as a whole.

In Table 5, the lowest dried density was mean 0.89 g/cc in five-aged branches and the highest dried density was 1.08 g/cc in one-aged branches in Sarilop fig cultivar. In Table 6, the lowest dried density was mean 0.58 g/cc in two aged branches and the highest dried density was 0.83 g/cc in four-aged branches in Sari Zeybek fig cultivar.

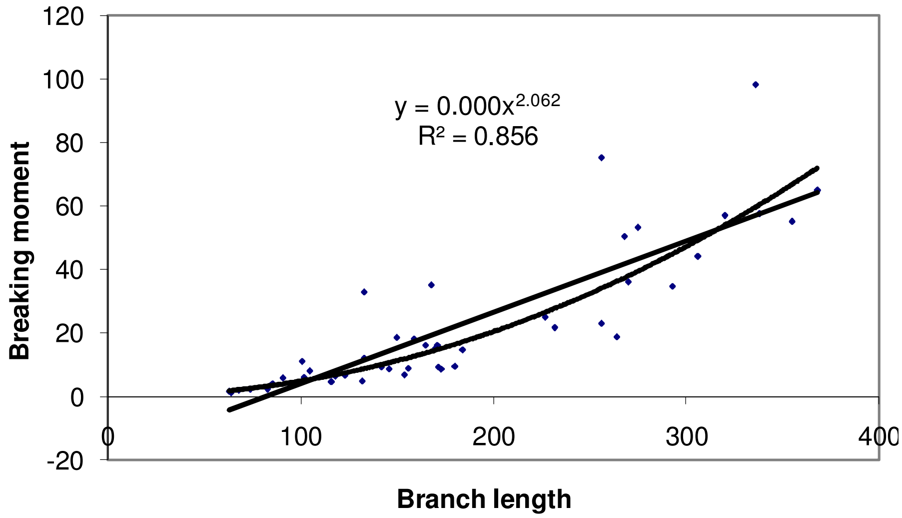

Figure 1. Relations between branch length and breaking moment. Appropriate regression equation was determined according to the highest R^2 coefficient.

Table 5. Densities of Sarilop fig cultivar on various age groups.

Sarilop	Fresh weight (g)	Fresh volume (ml)	Fresh density (g/cm³)	Dried weight (g) (40°C)	Dried volume (ml)	Dried density (g/cm³)
One-aged branch	20.45	25.00		4.87	5.00	
	22.10	23.50	0.90	5.67	5.00	1.08
	19.55	20.70		6.10	5.50	
Mean	20.70	23.06		5.55	5.16	
Two-aged branch	25.55	28.00		6.51	6.50	
	19.66	22.10	0.93	6.81	7.00	1.01
	13.74	14.10		7.18	6.80	
Mean	19.65	21.04		6.83	6.76	
Three-aged branch	27.60	28.00		6.61	6.50	
	29.50	31.10	0.96	7.49	8.00	0.98
	18.50	19.70		8.34	8.50	
Mean	25.20	26.26		7.48	7.66	
Four-aged branch	67.64	67.00		14.71	15.00	
	61.40	62.10	0.99	23.92	22.00	1.00
	54.50	56.10		18.61	20.00	
Mean	61.18	61.73		19.08	19.00	
Five-aged branch	50.28	55.00		9.20	10.00	
	47.40	49.10	0.95	16.31	18.00	0.89
	55.60	57.10		15.52	18.00	
Mean	51.09	53.73		13.67	15.33	

Variance analysis table for the statistical evaluation of dried weights between the same aged branches of Sarilop and Sari Zeybek fig cultivars is given in Table 7. As it is understood from Table 7, there is a crucial relation between clones and cultivar-branch ages with respect to dried sample densities. Statistical evaluations between the same aged branches were given in Table 8 as a whole.

Table 6. Densities of Sari Zeybek fig cultivar on various age groups.

Sari Zeybek	Fresh weight (g)	Fresh volume (ml)	Fresh density (g/cm³)	Dried weight (g) (40°C)	Dried volume (ml)	Dried density (g/cm³)
One-aged branch	20.45	25.00	0.85	4.14	6.00	
	18.50	22.10		3.47	4.50	
	17.45	18.90		2.04	4.00	
Mean	18.80	22.00		3.22	4.83	0.67
Two-aged branch	25.55	28.00	0.92	5.31	8.00	0.58
	21.40	23.10		3.86	7.00	
	17.55	18.70		3.62	7.00	
Mean	21.50	23.26		4.26	7.33	
Three-aged branch	27.60	28.00	0.96	32.69	48.00	0.74
	25.70	27.00		28.56	37.00	
	19.75	20.90		30.36	38.00	
Mean	24.35	25.30		30.54	41.00	
Four-aged branch	67.64	67.00	0.98	45.61	57.00	0.83
	55.80	57.00		45.43	55.00	
	47.85	50.10		42.19	48.00	
Mean	57.10	58.03		44.41	53.33	
Five-aged branch	50.28	55.00	0.94	10.92	15.00	0.80
	46.20	48.40		6.30	7.00	
	49.10	51.10		7.11	8.50	
Mean	48.53	51.50		8.11	10.17	

Table 7. Variance analysis table between branch ages and dried sample densities in Sarilop and Sari Zeybek fig cultivars.

Source of variation	Degree of freedom	Sum of square	Mean of square	F	5%	1%
Cultivar	1	0.517	0.517	93.789 **	4.350	8.100
Branch age	4	0.047	0.012	2.144 ns	2.870	4.430
Cultivar*age	4	0.148	0.037	6.703**	2.870	4.430
Error	20	0.110	0.006			
General	29	0.823	0.028			

Ns, Not significant; *, significant at 5% alpha level; **, significant at 1% alpha level.

As seen in Table 8, there is a significant statistical difference between the dried sample densities in the 1 to 5 aged branches of Sarilop and Sari Zeybek fig cultivars, and the dried sample densities in Sarilop fig cultivar are more than Sari Zeybek cultivar in these age groups. In the five aged branch samples, it was found that there was no difference in terms of dried sample densities between cultivars. The data on statistical evaluations, in order to investigate the dried sample densities between branch age groups, are given in Table 9.

Table 9 shows that there is a significant difference between the one and five aged branches of Sarilop cultivar in terms of dried sample density. However, it is found that there is no statistical difference between the densities in the two, three and four aged branches and the one and five aged branches. In Sari Zeybek cultivar, no difference was observed between the densities of the one and two aged branches. Also, the three, four and five year aged branches had no difference within themselves and when compared to the one year aged branches. Following these statistical evaluations, it was found that both cultivars did not demonstrate significant changes in

Table 8. Relation between the dried sample densities that are on the same aged branches of cultivars.

Branch age	Sarilop*	Sari zeybek*
1	1.070[a]	0.657[b]
2	1.010[a]	0.577[b]
3	0.980[a]	0.750[b]
4	1.000[a]	0.837[b]
5	0.897[a]	0.823[a]

*: Significant at alpha level 5%, LSD = 0.127.

Table 9. Relations between the dried sample densities of the cultivars that are in the 1 to 5 aged branches, separately.

Branch age	Sarilop*	Sari zeybek*
1	1.070[A]	0.657[AB]
2	1.010[AB]	0.577[B]
3	0.980[AB]	0.750[A]
4	1.000[AB]	0.837[A]
5	0.897[B]	0.823[A]

*: Significant at alpha level 5%, LSD = 0.127.

xylem densities, which meant that xylem densities did not have significant changes depending on age.

Conclusion

At the end of the investigation, breaking forces were exerted on the branch collars, which changed with branch age in Sari Zeybek fig variety. Thus, the obtained results and the performed statistical analyses stated that the breaking moments increased parallel to the increased branch ages; and in another point of view, the force needed for breaking was exerted more on the branch canopy. Occurrence of this change, after 4 to 5 years, provides an insight to the fact that the problem is more commonly seen at these ages in the field. This evaluation reveals that increasing the branch lengths and diameters by age, increased the branch mass. Also, the leaf and fruit load on it increased. So, the level arm (branch length) gets longer, which results to an increase in the exerted force of the branch collar. Thus, this leads the increased total load (branch mass, branch length, leaf and fruit load), consequent to vegetative growing after 4 to 5 years, to be unavoidable and it seems to be the main cause of branch breaking. Absence of significant increase in densities as the branches get older is not sufficient to prevent this branch breaking problem in this variety. In spite of these evaluations, the facts that either anatomic and histological structures or branch age density values in the five-year aged branches were similar between Sarilop and Sari Zeybek fig cultivars, and also between the Sarilop cultivars which resisted extreme force exertions (150 kg), brought the possible relation of branch breaking with tissue elasticity into question. The same aged Sari Zeybek cultivar with branch breaking problems and Sarilop cultivar, with which no breaking was observed, should be considered for comparison with respect to cellulose, hemicellulose and lignin contents. The results provided from this comparison may lead to a case that is more certain.

The results of this study provide a conclusion that older branches have increased length and diameter, and after 4 to 5 years, they increased the fruit load that exerts more force on branch collars in Sari Zeybek fig cultivar. This load promoted branch breaking, so formative pruning between the first and fourth year came into prominence in Sari Zeybek fig cultivar. A formative pruning that controls branch length and forms the main structure where branching occurrence is avoided from close sites should be anticipated. Besides, yield pruning that does not extremely promote vegetative development should be mild.

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