Contributions of Short- and Long-Shoots to Yield of 'Kerman' Pistachio

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Abstract

The canopy of a mature pistachio (*Pistacia vera* L.) tree is composed of two types of shoots: short-shoots composed entirely of preformed units, and long-shoots composed of both preformed and neoformed units. Since the production of these two types of shoots is known to be related to rootstock and rootstock influences yield of pistachio the relationship of these two types of shoots to yield was investigated during two cropping years. Short-shoots produced significantly less total yield and had fewer fruit clusters per shoot compared with long-shoots. Long-shoots positively affected yield components in one year, but had no effect in the other year. Whether the differences in the one year were due to canopy position and light interception or differences in the carbohydrate allocation within the two types of shoots could not be determined from the current data. Long-shoots initiated more inflorescence buds, although inflorescence bud formation was restricted to the preformed growth and only the 3-4 earliest neoformed nodes. However, when expressed as a percentage, long-shoots retained a lower percentage of initiated inflorescence buds, compared with short-shoots. Regardless of shoot type, less than half of the inflorescence buds that were retained from the previous season produced mature fruit clusters, indicating that inflorescence bud retention from the previous season may not be the primary limiting factor to yield in pistachio.

INTRODUCTION

The marketed pistachio nut, the fruit of *Pistacia vera* L., is comprised of a shell (endocarp) and kernel (seed), with a fleshy hull (mesocarp) which is removed during processing. Endocarp dehiscence, or shell splitting, occurs naturally in approximately 65% of commercially harvested nuts in California, and is an important feature in the marketing of pistachio nuts. The accepted theory is that pistachio dehiscence is a physical phenomenon resulting from outward pressure of the developing kernel on the shell (Polito and Pinney, 1999). This is supported by reports of larger kernel size of split nuts compared with non-split nuts (Crane and Iwakiri, 1982; Polito and Pinney, 1999). Therefore, it is logical that factors affecting kernel size, whether positively or negatively, also alter the percentage of split nuts.

The majority (~90%) of the shoots in mature pistachio canopies are preformed short-shoots that finish growing by mid- to late-May (Spann et al., 2007). Thus the majority of shoot growth does not have the potential to compete with the kernel development stage of fruit growth which begins in early July (Polito and Pinney, 1999). Any direct potential competition between short-shoot growth and nut growth could only take place during the shell expansion stage of nut development (late April through late May), and may actually enhance shell splitting by restricting shell size. About 10% of the shoots in the canopy of normally pruned pistachio trees on vigorous rootstocks are long-shoots produced from neoformed growth (Spann et al., 2007). These shoots continue growing much later into the season than their shorter counterparts. Long-shoot growth, therefore, could directly compete with the kernel development stage of nut growth.

The mechanism for alternate bearing in pistachio appears to be unique to the genus *Pistacia*. In most alternate bearing tree crops flower bud initiation is inhibited when a crop is present (Monselise and Goldschmidt, 1982). However, in pistachio flower buds are produced in abundance each year, regardless of crop load, but they abscise in large numbers at the onset of kernel development (early July in California) when large crops are present (Crane and Iwakiri, 1981). The percentage of flower buds retained at the end of a season is thought to be a measure of the tree's yield potential the following season (Beede, pers. commun.). Observations indicate that long-shoots, because of their greater number of nodes, may have the potential to initiate more flower buds; however, it is unclear what effect shoot type has on final bud retention.

The objectives of this study were to (1) determine if long-shoots are more productive than short-shoots, and if the proportions of split, non-split and blank nuts varied by shoot type, (2) determine the relationship between shoot type and inflorescence bud initiation and retention (i.e. yield potential), and (3) determine the relative importance of short- and long-shoots to total yield of mature pistachio trees growing on different rootstocks.

MATERIALS AND METHODS

Plant Material

All experiments were conducted in a rootstock trial block located at the University of California, Kearney Agricultural Center, Parlier, CA. The block was planted in 1989 and consisted of 90 trees on each of four rootstocks budded with the cultivar 'Kerman'. The planting and irrigation design were described fully by Ferguson et al. (1998). Prior to the beginning of these experiments in 2002, all trees had been grown according to standard commercial practices (Ferguson et al., 2005). The current research only used trees on *Pistacia atlantica* Desf. (Atl), *P. integerrima* Stew. (PGI) and *P. atlantica* × *P. integerrima* (UCB) rootstocks.

Components of Yield

To study the effects of shoot type (short or long) on the components of yield three trees on the UCB rootstock were hand harvested at full nut maturity in 2003 and 2004. The same three trees were harvested each year. Based on historical averages, 2003 was predicted to be an off-year and 2004 an on-year. The nuts from each stem were removed and placed in separate bags. The length, number of nodes, and type of shoot was recorded for the current season growth distal to the nut clusters on each bearing stem, additionally the number of clusters per stem was recorded in 2004. The nuts from each stem were hand hulled the day of harvest. The hulled nuts were then sorted into split, non-split and blank nuts before drying.

Whole Tree Cluster Data

To determine the source of yield differences among the three rootstocks, three "on" trees on each rootstock were hand harvested at full nut maturity in 2005. Prior to the full tree harvest, a 50 cluster sample was collected from each tree. Sampled clusters were collected from the uppermost portion of the canopy, regardless of shoot type, on each tree to eliminate variation due to canopy location. The remaining clusters on each tree were then removed and counted to determine the total number of clusters per tree. The nuts were separated from the rachises for one tree to determine the ratio of rachises to nuts on a fresh weight basis, this factor was applied to the total fresh weight of each remaining tree to determine a total nut fresh weight per tree. Each of the 50 clusters sampled from each tree were hand sorted into split, non-split and blank nuts and the fresh weight of each component was recorded.

Inflorescence Bud Retention in "Off" Year Trees

Shortly after bloom in 2003 several trees on each rootstock that had produced a crop in 2002, and, therefore, were naturally "off", had all inflorescences removed by hand to produce completely “off” trees. At the end of 2003, three of these “off” trees (one per rootstock) adjacent to one another were selected and the number of inflorescence buds initiated and retained were counted for 30 short- and 30 long-shoots on each tree. Shoots were selected from full sun positions in the upper portion of the canopy to eliminate variation due to canopy position or shading. The percentage of buds retained was calculated by dividing the number of buds retained by the total number of buds initiated on each shoot.

RESULTS

Components of Yield and Total Yield by Shoot Type

Components of yield data were similar in 2003 and 2004, thus only 2004 data are presented. There were considerably more fruitful short-shoots than long-shoots per tree (Table 1) and short-shoots collectively produced a greater portion of the total tree yield. Although, individual long-shoots produced significantly higher yields on a dry weight basis compared with individual short-shoots (Table 1). This difference was reflected in an average of one more fruit cluster per shoot on long-shoots compared with short-shoots (Table 1). The average number of nuts per cluster was not significantly different, although there was a trend toward fewer nuts per cluster on short-shoots.

The percentage of split nuts was significantly greater for long- compared with short-shoots in 2004 (Table 1). This increase was coincident with a significant decrease in the percentage of non-split and blank nuts on long-shoots. Although not significant, there was a similar pattern of greater split nuts and fewer non-split and blank nuts in 2003 for long- compared with short-shoots (data not shown).

Whole Tree Cluster Data

The number of clusters per tree was significantly less for trees on Atl rootstock compared with those on PGI or UCB (Table 2). However, the number of nuts per cluster and the average cluster fresh weight, calculated from a 50 cluster sample, were similar across rootstocks.

Inflorescence Bud Retention

The absolute number of inflorescence buds retained was significantly greater for long-shoots (average 7.8) compared with short-shoots (average 6.1) for trees on all rootstocks, reflecting the greater number of buds set on long-shoots (average 12.6 vs. 8.6), but long-shoots retained a significantly lower percentage (60.0%) of inflorescence buds compared with short-shoots (70.9%) across all rootstocks.

DISCUSSION

Historically, pistachio trees grown on PGI and UCB rootstocks in California produce significantly higher yields than trees on Atl (Ferguson et al., 2005). This difference has generally been attributed to the larger size of trees grown on UCB and PGI rootstocks and thus more fruit clusters per tree, as opposed to more nuts per cluster (Ferguson et al., 2005). The data presented here support the attribution of yield differences to more fruit clusters per tree and not to differences in cluster size (Table 2) among rootstocks. However, our previous research has shown that trees on PGI and UCB rootstocks also produce more shoots with neoformed growth (i.e., long-shoots) than do trees on Atl (Spann et al., 2007). Therefore we thought that it would be beneficial to examine yield differences between the short- (preformed) and long-shoots (composed of preformed and neoformed growth) within a canopy to determine the contribution of each shoot type to yield.

Whole tree harvest data of trees on UCB rootstocks over two years showed that long-shoots produced significantly higher yields than short-shoots (Table 1). These higher yields were associated with significantly more clusters per shoot as well as a trend toward more nuts per cluster.

Long-shoots produced significantly more split nuts compared with short-shoots in 2004. Shell splitting is a physical phenomenon in pistachio (Polito and Pinney, 1999) and split nuts typically have a greater kernel dry weight than non-split nuts (Crane and Iwakiri, 1982). This indicates that shell splitting may be dependent on carbohydrate production and availability. Since most long-shoots are found in the top of the canopy where light interception is greatest it is logical that there would be greater carbohydrate availability to drive kernel development and consequently shell splitting on these shoots. Therefore, the greater percent of split nuts on long-shoots in 2004 may be due to greater shoot leaf area and thus carbohydrate production.

Because inflorescence bud abortion has been positively correlated with crop load (Crane and Nelson, 1971; Crane and Nelson, 1972; Wolpert and Ferguson, 1990) it has been viewed as the cause of alternate bearing in pistachio (Ferguson et al., 2005). Thus, bud retention is generally used as an indicator of yield potential the next season (Beede, personal communication). Given the greater number of nodes on long-shoots the absolute number of buds initiated was significantly higher compared with short-shoots. However, long-shoots of pistachio typically have as many as 25 nodes (Spann et al., 2007), but only set an average of four inflorescence buds more than short-shoots. Thus the majority of the neoformed nodes on long-shoots did not initiate inflorescence buds. It has been reported that floral bud initiation for the next year's crop begins very soon after new growth emerges in late March and early April (Hormaza and Polito, 1996), and, therefore many of the neoformed nodes were likely produced after floral initiation had taken place. Thus, only the earliest formed neoformed nodes initiated inflorescence buds and the majority of inflorescence buds were initiated on the preformed portion of long-shoots.

Ultimately, long-shoots retained only ~1.5 more inflorescence buds than short-shoots; thus, retaining a significantly lower percentage of set inflorescence buds compared with short-shoots. Therefore, the ongoing production of neoformed growth on the long-shoots appears to have negatively affected percent bud retention. Crane and Nelson (1972) and Crane et al. (1973) suggested that assimilate depletion was responsible for bud abscission in pistachio. Thus, it could be hypothesized that the continued neoformed growth of long pistachio shoots reduced assimilate availability and relative bud retention.

Although significant differences were observed in total yield per shoot, the number of fruit clusters per shoot, yield components and inflorescence bud retention between short- and long-shoots, it could not be determined whether these differences were related to canopy position and light exposure or to carbohydrate allocation changes associated with these two types of shoots.

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Tables

Table 1. Number of fruiting shoots, dry yield, fruit cluster data and components of yield for short- and long-shoots of 16-year-old 'Kerman' pistachio trees on UCB rootstock in 2004.

Shoot type	Avg no. fruiting shoots/tree	Total average yield/tree (kg)	Average yield/shoot (g)	Clusters/shoot	Nuts/cluster	Yield components (%)		
						Split nuts	Non-split nuts	Blank nuts
Short	259.0	7.87	30.4	2.3	12.7	42.6	32.0	25.4
Long	55.3	3.90	70.4	3.2	18.5	58.2	20.6	21.2
LSD (*P*=0.05)		3.69	5.6	0.3	11.0	3.6	3.5	3.2

Table 2. Total number of nut clusters per tree, number of nuts per cluster and average cluster weight for 16-year-old 'Kerman' pistachio trees grown on three rootstocks in 2005.

Rootstock	No. of clusters per tree	No. of nuts per cluster[y]	Sampled average cluster FW (g)[z]
Atl	482.0 ± 103.24b[y]	19.71 ± 0.67a	57.33 ± 5.52a
PGI	1105.0 ± 106.13ab	18.39 ± 0.88a	52.38 ± 1.88a
UCB	1608.0 ± 537.96a	16.54 ± 2.88a	53.85 ± 11.28a

[z]Values are means ± SD calculated from a 50 cluster sub-sample per tree, three trees per rootstock.
[y]Mean separation within columns by Duncan's multiple range test, *P*=0.05.