WALNUT PRODUCTION AND QUALITY AS INFLUENCED BY ORCHARD AND WITHIN TREE CANOPY ENVIRONMENT

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ABSTRACT

There are differences in walnut quality through the tree canopy which may be related to water relations and/or light gradients. We have made significant progress on understanding the role of canopy position and light exposure on quality related problems in walnut. The data we have at present suggests that photosynthate reduction early in the season results in shriveled nuts while later restriction results in either yellow or black pellicles, depending on the timing. Some of the yellow nuts occurred in positions where the spur was in a well lit position early in the season but became shaded as the season progressed due to higher limbs coming down on top of them. All of the nuts with yellow and black pellicles had a mushy, wet hull surrounding the nut. The photosynthate reduction can be caused by low light conditions and/or loss of leaves. In addition, it appears that orchards running near the fully watered baseline (in the -4 to -5.5 bar midday stem water potential range) have a decrease in nut quality compared to orchards in the -6 to -7 bar range although the mechanism is not yet known.

INTRODUCTION

A study was set up in two Chandler walnut orchards in San Joaquin County. The first orchard was planted in 1998 and has 30’ x 30’ equilateral triangle layout. The second orchard was planted in 1994 and also has a 30’ x 30’ equilateral triangle layout. Both orchards have a history of producing kernels with a yellow pellicle. The grower has observed that the problem is worse at about 9 years of age and tends to be less severe as the orchard ages beyond 9 years.

PROBLEM AND SIGNIFICANCE

Walnut quality can vary within the tree canopy. The differences are likely related to both water relations and light distribution. Outer, exposed nuts can be susceptible to sunburn related damage. In addition to these more easily visible, outer canopy nuts, many walnut quality problems also occur in inner canopy, shaded positions. The authors have observed that these problems tend to be most severe in productive orchards with a high percentage of midday canopy light interception. Examples of the problems that have been observed in these inner canopy shaded positions include shriveled kernels, oilless nuts, the black Chandler problem and more recently kernels with yellow pellicles. All of these problems can have significant impacts on walnut yield and/or quality.

The relationship between orchard design, light interception and the potential impacts of these factors on nut quality is largely unknown.

The goal of this project is to investigate the role of orchard structure, tree physiology and microenvironmental conditions within the tree canopy on resulting nut quality. The intent is to use this information to aid in orchard layout, tree training and canopy management in order to maximize productivity and quality.

BACKGROUND

Walnut sizing occurs during the first 14 weeks after bloom. Kernel filling begins about 8 weeks after bloom and continues until about 20 weeks after bloom. Interruptions in carbon availability, which could be caused by lack of water, excess water, excessive heat, etc. during the first 14 weeks after bloom can result in smaller sized nuts while interruptions from 8 to 20 weeks after bloom can result in kernel filling and or quality problems. Any of these stresses likely would have more severe impacts on nuts in interior, shaded positions.

OBJECTIVES

The goal of this project is to monitor conditions throughout the tree canopy during the kernel filling period and attempt to relate these conditions to resulting kernel development and quality.

MATERIALS AND METHODS

A study was set up in two Chandler walnut orchards in San Joaquin County. The first orchard was planted in 1998 and has 26' x 26' equilateral triangle layout. The second orchard was planted in 1994 and also has a 26' x 26' equilateral triangle layout. Both orchards have a history of producing kernels with a yellow pellicle. The grower has observed that the problem is worse at about 9 years of age and tends to be less severe as the orchard ages beyond 9 years.

Four irrigation treatments were set up in each orchard in 2007 and 2008. Treatments included a fully irrigated control and treatments with water cutoffs on Aug. 1, Aug. 15, and Aug. 30. Each replication consisted of three rows and approximately seven trees per row. Midday stem water potential was measured approximately weekly on five trees in each of the four irrigation treatments in both orchards. In May 2007, all nuts on 25 spurs were tagged on each of the five monitored trees in each treatment (total of 1000 spurs). The spurs were tagged in the pattern shown in Fig. 1. Spur survival was followed on the same tagged spurs in 2008. Midday canopy light interception for the overall orchard and midday canopy light interception directly underneath the tree canopy were measured approximately every 1-2 weeks during the growing season using a Decagon Sunfleck Ceptometer (Decagon Devices, Pullman, WA 99163). The number of yellow leaves and the number of nuts that dropped beneath each monitored tree were also measured approximately every 1-2 weeks.

The diameters of the tagged nuts were measured at the time of tagging in late May and again in late July in 2007. In late July, one tree in each orchard was outfitted with individual photodiodes on one nut and one terminal leaflet on each tagged spur (total of 50 photodiodes per tree). The photodiodes measured the incident light falling on the nut and leaf. Data was recorded on a Campbell Scientific CR10 datalogger at one minute intervals for 3 days in each orchard. On the two trees that had the light sensors attached, an adjacent spur (selected to have similar characteristics to the monitored spur) was sampled and used for measurement of leaf area as well

as leaf specific mass. Leaf disks were taken with a cork borer from each of the terminal leaflets on all tagged spurs in early September. The leaf disks were dried and weighed to determine leaf specific mass expressed as grams of dry weight per meter squared of leaf area. Number of leaves per spur was counted in May 2007. The longest leaf (south orchard only) and the number of leaves on each tagged spur were counted on each tagged spur in late September 2007.

Temperature and relative humidity were monitored in one control tree in each orchard Data was collected at 0.5 to 1 hour intervals throughout the season.

PRELIMINARY RESULTS AND DISCUSSION

Water potentials generally ran about 1 to 2 bars less stressed in the 9 year old orchard than in the 13 year old orchard in both 2007 and 2008 (Fig.2). When irrigation was stopped in 2007, water potentials tended to drop off more rapidly in the 13 year old orchard than in the 9 year old orchard on the Aug. 1 and Aug. 15 cutoff dates but not on the Aug. 30 cutoff date (Fig. 2). Results in 2008 were similar to those in 2007 (Fig. 2). Because the irrigation system was only operated once per week, desired levels of stress were not always reached since if the level was near the target but not quite there, another week might have resulted in overshooting the target with potentially damaging effects on yield or quality.

Midday canopy light interception was very high in both orchards with overall orchard levels at a averaging 90.3 percent in the 13 year old orchard and 88.1% in the 9 year old orchard and 99% underneath the tree canopy in 2007 (Table 2). There was significantly higher overall midday canopy light interception in the 13 year old orchard compared to the 9 year old orchard in both years (Table 2). Seasonal average results in 2008 were similar to those in 2007 (Table 2). These are very high levels of light interception which would be expected to result in shading related dieback of lower leaves based on our earlier data from other walnut orchards. Although we did see dieback of lower leaves and branches, it was not as high as the authors would have expected based on previous data. There are two management related issues that may have acted to help minimize shading related dieback. First, the trees were kept very near the fully irrigated baseline throughout the season since the grower uses a pressure chamber to aid in irrigation scheduling. This means that leaves that might otherwise have become a net negative and dropped, might have stayed a net positive for a longer period. Most orchards would go through some stress cycles at some time during the season that would cause some of these lower leaves to abort. The second management practice that may have helped to minimize shading related dieback was a pruning program that was done before the 2007 season and during the summer of 2007 which had a goal of selectively removing higher canopy limbs to increase light penetration lower into the canopy with the goal of preserving lower fruiting wood.

Although there was an increase in yellowing and leaf drop in the lower canopy associated with the irrigation cutoff treatments in 2007 (Table 1), it was not enough to cause a noticeable change in midday canopy light interception in any of the treatments in either orchard. The increase in leaf drop associated with cutoff treatments within either orchard was only significant for the August 1 cutoff date in the 13 year old orchard in 2007 (Table 1). Results in 2008 were similar to those in 2007 except in the 9 year old orchard, the no-cutoff treatment had significantly higher leaf drop in the 9 year old orchard (Table 1). There was no increase in dropped nuts associated

with any of the treatments in either year (Table 1). However, there likely were effects on nut sizing and quality on individual spurs that lost their leaves.

Leaf specific weight varied across the tagged spurs with the lowest leaf specific weight in the lower middle of the tree (Fig. 3a). Leaf specific weight was slightly higher in the 13 year old orchard (north) compared to the 9 year old orchard (south). This would be consistent with the observation of the grower that quality problems were less severe in older orchards since a higher leaf specific weight indicates higher light levels at that position. Reflectance was variable with the lowest values occurring in the 9 year old orchard (south) in the lower middle positions. Again, this difference between orchards is consistent with quality problems becoming less of a problem as the orchard ages.

The total kernel dry weight at the time of harvest was greater on spurs with two nuts as compared to those with one nut (see 2007 report on this project for data). This suggests that spurs with one nut may be able to build up more reserves in store for the following year compared to spurs with two nuts which would likely be more depleted of reserves. Severely shriveled nuts tended to be on spurs with very low leaf dry weights (and a small number of leaves) suggesting that light conditions limited photosynthate available for kernel growth (data not shown). Interestingly, nuts on spurs with very high dry weights (i.e. high light exposure) tended to have slight kernel shrivel as well. These conditions were associated with the most outer canopy exposed positions and often usually had actively growing shoots that were likely competing for carbon with the nuts.

The percentage of yellow kernels in these two orchards was extremely small in 2007 and again in 2008. The growers' records indicate that there were less than 1% of the nuts with yellow kernels in these two orchards in 2007 and similar levels in 2008. Yellow nuts occurred on 8.3% of the tagged nuts in the south orchard (9 years old) and on 3.2% of the tagged nuts in the north orchard (13 years old; Fig. 4). Yellow nuts occurred across the tagged positions with a higher percentage occurring near the lower, center of the tree, particular in the south orchard (Fig. 4). The reason for the higher proportion of yellow nuts on our tagged spurs compared to the overall orchard is likely because our tags were concentrated in the lower areas of the canopy where the problem occurs most frequently.

The difference between conditions that produce shriveled kernels versus yellow and black kernels is likely the timing of photosynthate restriction to the spur, either due to shading, leaf loss or some combination of the two. 85% of the dark kernels came from the middle 15 tagged positions and many of these spurs had 3 or fewer leaves in May suggesting that the problem actually started the previous year (data not shown). Most nuts that dropped before Sept. 15 had moderate to severe quality problems including shriveled kernels and/or dark pellicle color (data not shown). Many of these kernels would not end up in the processing chain since they would be separated out by the harvester due to their light weight.

In summary, we have made significant progress on understanding the role of canopy position and light exposure on quality related problems in walnut. It appears that shading related pellicle darkening and shrivel is associated with low light levels on interior canopy positions. Nuts with yellow and black pellicles occurred on branches that also had problems with photosynthate restriction, either from lack of light or leaf loss or a combination of the two. Some of the yellow

nuts occurred in positions where they were in a well lit position early in the season but became shaded as the season progressed due to higher limbs coming down on top of them. All of the nuts with yellow and black pellicles had a mushy, wet hull surrounding the nut.

It appears that orchards running near the fully watered baseline (in the -4 to -5.5 bar midday stem water potential range) may have a decrease in nut quality although the mechanism is not yet understood. Across the -4 to -8 bar seasonal average midday stem water potential range observed in this study, reflective light index (RLI) and relative value increased with increasing levels of stress in 2007 and 2008 although the relationship was different in each year (Fig. 5).

Unfortunately the data collected to date does not allow us to accurately pinpoint the timing of photosynthate restriction that results in the different quality problems. The data we have at present suggests that photosynthate reduction early in the season results in shriveled nuts while later restriction results in either yellow or black pellicles, depending on the timing. It is possible that the difference in yellow versus black colored pellicles depends on the temperature at the time the wet conditions occur surrounding the kernel. Fig. 6 shows the relationship between the kernel weight in grams and the reflectance (higher number is lighter pellicle). The shriveled nuts are grouped in low kernel weights and low reflectance. The yellow nuts span across the same kernel weight and reflectance range as the good nuts while the black and nuts with black pellicles tend to be at the lighter kernel weight range of good nuts. This suggests that the yellow nuts may result when the wet conditions around the kernel occur late in the development period while the black nuts may occur somewhat later. In October 2008, we artificially created wet conditions around the shell by burying nuts in wet soil and this produced nuts with yellow pellicles. In 2009, we plan to do artificial removal of leaves (in lower canopy positions) during the July to September period to more accurately pinpoint when the different quality problems occur in relation to the time leaves are lost.

ACKNOWLEDGEMENTS

Thanks to the Walnut Marketing Board, the Barton Ranch and Diamond Foods, Inc. for supporting this work.

TABLES AND FIGURES

Table 1. Average number of yellow leaves and dropped nuts by orchard and treatment. Letters indicate significant difference between orchards.

2007	Ave. yellow leaves				Ave. dropped nuts			
Orchard	No-cutoff	Aug-1	Aug-15	Aug-30	No-cutoff	Aug-1	Aug-15	Aug-30
13 yr old (north)	4.58 a	11.93* a	7.60 a	6.61 a	2.60 a	3.00 a	1.92 a	1.72 a
9 yr old (south)	2.04 b	3.07 b	3.02 b	2.38 b	1.50 a	1.62 a	2.12 a	2.10 a

2008	Ave. yellow leaves				Ave. dropped nuts			
Orchard	No-cutoff	Aug-1	Aug-15	Aug-30	No-cutoff	Aug-1	Aug-15	Aug-30
13 yr old (north)	24.1 a	25.0 a	25.4 a	13.8 a	13.4 a	13.4 a	13.4 a	10.5 a
9 yr old (south)	22.1* b	9.3 b	6.9 b	8.1 b	12.9 a	8.0 a	11.7 a	8.7 a

*significantly different from all other treatments- only significant difference between treatments

Table 2. Midday stem water potential, light interception and quality differences between the 13 and 9 year old orchards.

2007

Orchard	**Seasonal average MSWP**	**Midday light interception (%)**	**Light interception under tree canopy (%)**	**Average nut weight (g)**	**Mold (%)**	**RLI**	**Relative value**
13 yr old (north)	-6.34 b	90.3 a	99.0 a	11.48 a	0.70 a	56.52 a	1.028 a
9 yr old (south)	-4.83 a	88.1 b	99.2 a	11.06 b	1.30 a	55.40 b	1.003 b

2008

Orchard	**Seasonal average MSWP**	**Midday light interception (%)**	**Light interception under tree canopy (%)**	**Average nut weight (g)**	**Mold (%)**	**RLI**	**Relative value**
13 yr old (north)	-5.79 b	92.5 a	97.8 b	10.40 a	1.3 a	56.84 a	1.037 a
9 yr old (south)	-4.84 a	91.5 b	98.8 a	10.40 a	2.0 a	55.84 b	1.019 b

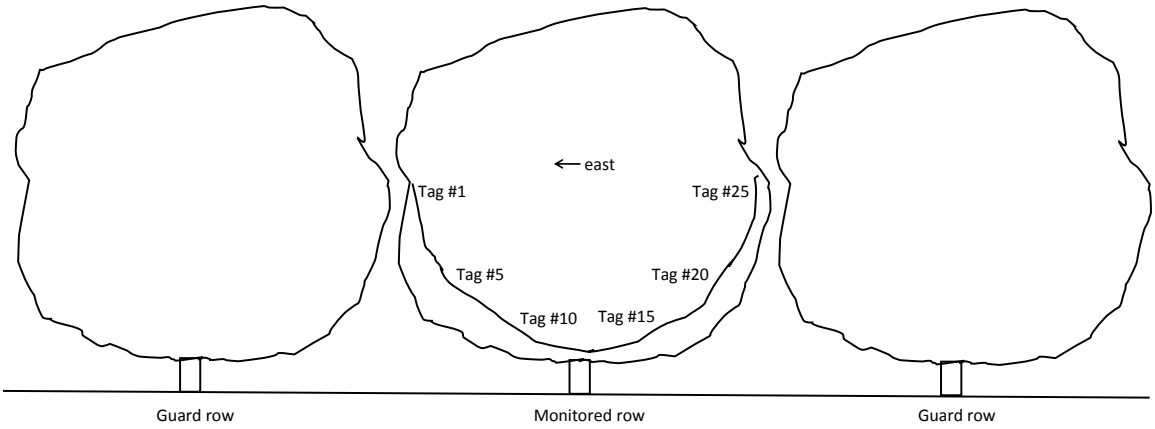

Fig. 1. Pattern and tag numberings system for all trees in both orchards

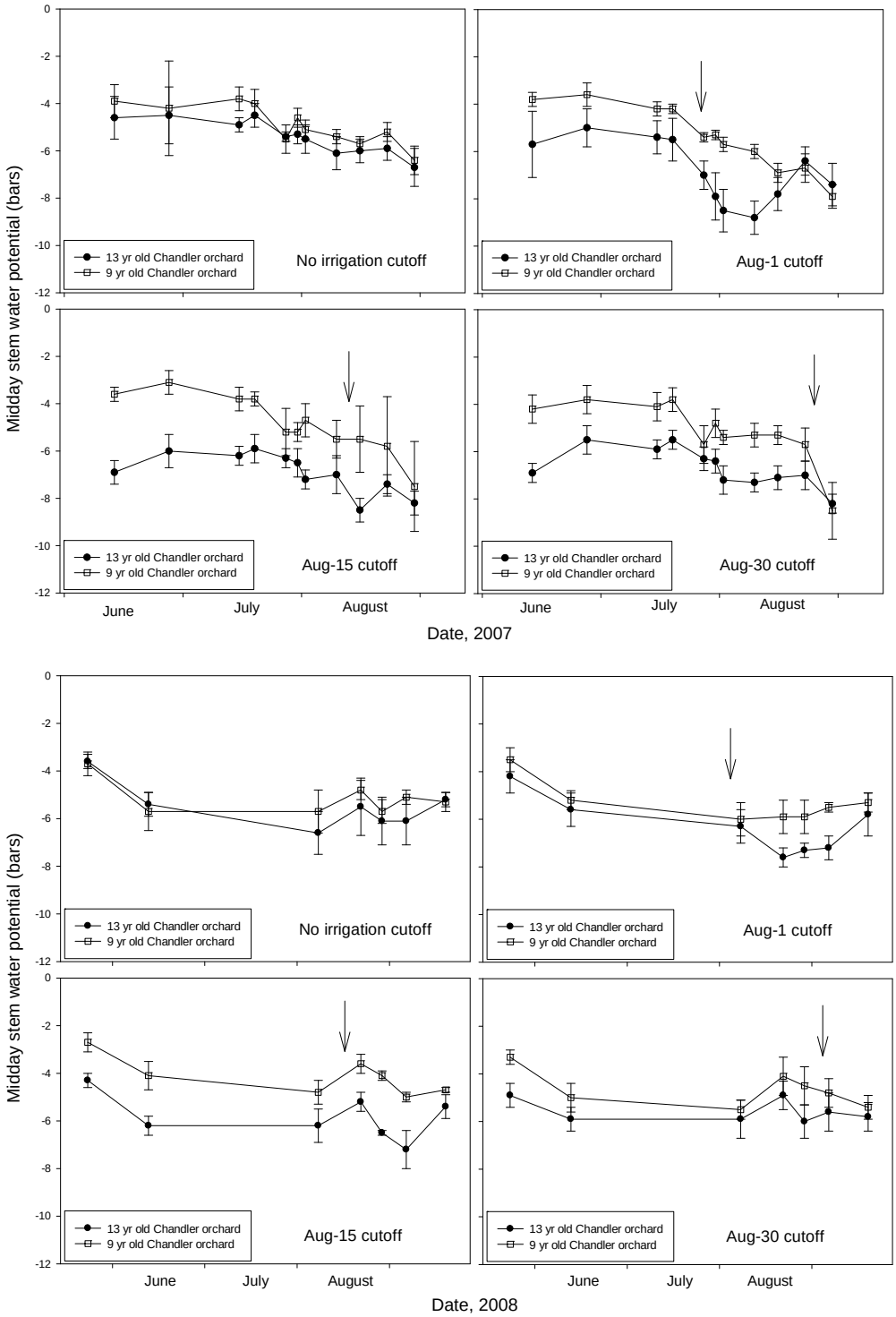

Fig. 2. Midday stem water potential by irrigation treatment and orchard. Arrows indicate approximate date of irrigation cutoff. The 13 year old orchard is the north orchard and the 9 year old orchard is the south orchard.

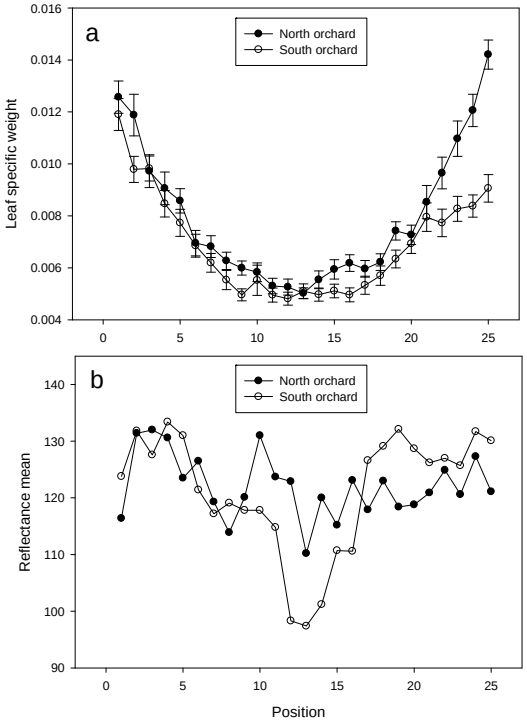

Fig. 3. Canopy position versus (a) leaf specific weight and (b) mean reflectance for the north and south orchards. Canopy position is described in Fig.2. Data is for all 20 monitored trees in each orchard.

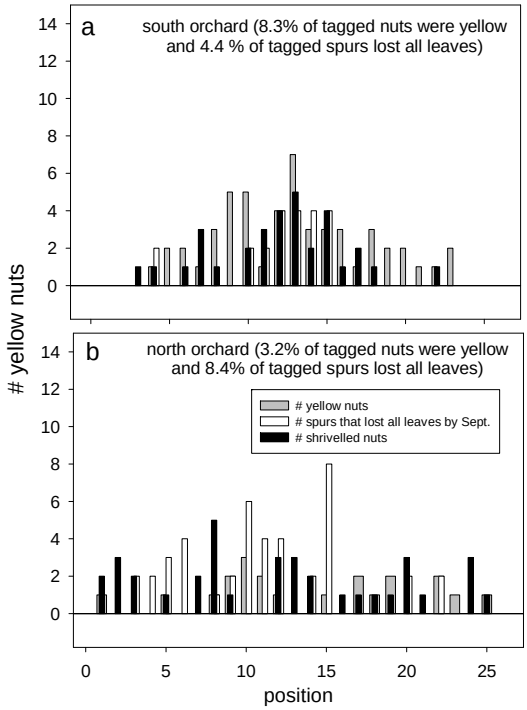

Fig. 4. Canopy position (as described in Fig. 2) versus the number of yellow nuts recovered at that position for the south and north orchard in 2007. The south orchard was 9 years old and the north orchard 13 years old in 2007.

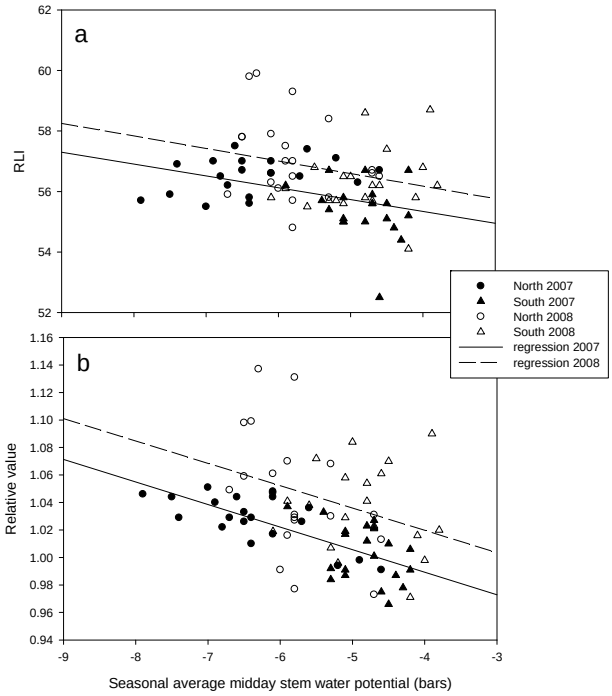

Fig. 5. Relationship between seasonal average midday stem water potential and (a) reflected light index (RLI) and (b) relative value nut value (as evaluated by Diamond Walnut) for the south (9 year old) and north (13 year old) orchards. Regression line is fit to data from both orchards combined separated by year.

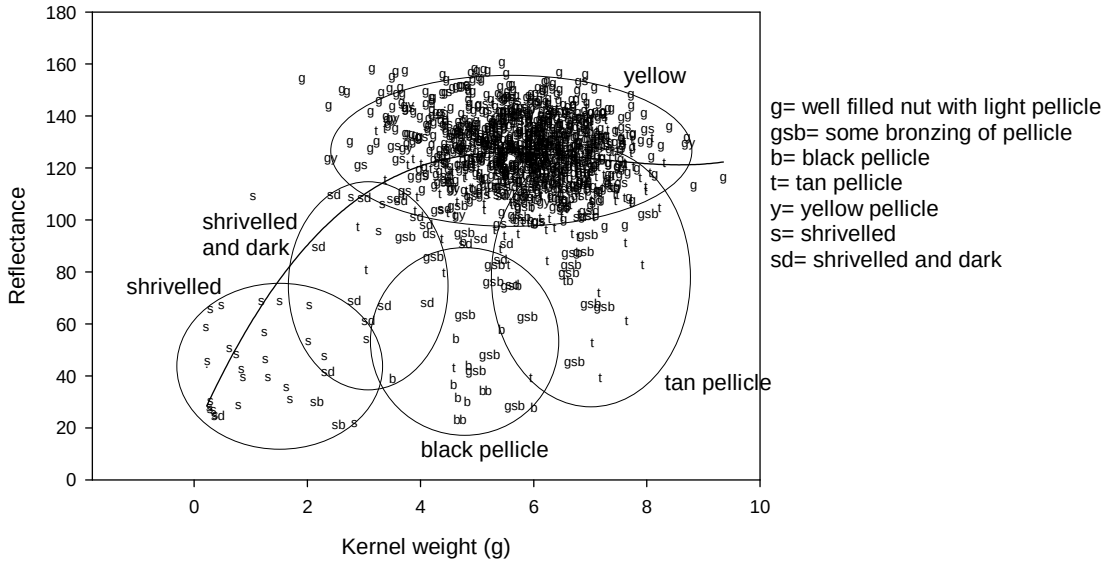

Fig. 6. Kernel weight versus reflectance for all recovered nuts. Circled areas indicate where the main concentration of each nut category was found.