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Effects of Different Levels of Preharvest Shading on the Storage Quality of Strawberry (*Fragaria* x *ananassa* Duchesne) cv. Ostara I. Physical Characteristics

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ABSTRAK

Kajian ke atas kesan penaungan terhadap kualiti buah strawberi (Fragaria x ananassa *Duchesne) cv. Ostara dari peringkat perkembangan buah hingga pemetikan telah dijalankan. Pokok strawberi telah diberi penaungan dengan jaring yang mempunyai darjah penembusan cahaya yang berlainan (74, 58, 48, 38 dan 5% yang dilambangkan sebagai S_0, S_1, S_2, S_3 dan S_4 masing-masing). Hasil kajian menunjukkan kesan penaungan hanya boleh dilihat apabila pokok diberi penembusan cahaya yang paling rendah, S_4. Kedudukan buah di pokok mempengerahui berat segar buah, kilauan kulit buah dan kekerasan buah dengan bererti. Buah yang dinaungi oleh daun didapati lebih berat dan berupaya mengekalkan kilauan kulit buah lebih lama berbanding dengan buah yang terdedah.*

ABSTRACT

The effects of shading developing fruits up to harvest on strawberry (Fragaria x ananassa *Duchesne) cv. 'Ostara' fruit quality were studied. Plants were shaded with netting of different levels of light penetration (74, 58, 48, 38 and 5% which are denoted by S_0, S_1, S_2, S_3 and S_4 respectively). Results showed that effects could only be detected when plants were subjected to a very low level of light intensity, S_4. Location of fruits on the plant affected the fresh fruit weight, surface glossiness and fruit firmness significantly. Fruits shaded by leaves were heavier and able to retain surface glossiness longer than exposed fruits.*

INTRODUCTION

Strawberries have a severe postharvest loss potential due to their fragile nature and high respiratory activity (Mitchell 1985). The skin is tender and thus is easily injured subjecting the fruits to easy invasion by fruit rotting organisms. When freshly picked, strawberry fruits have a smooth, glossy cuticle which give them their bright sparkling appearance (Skene 1971). However, the shine on strawberries disappears if held for a few days after picking (Topping 1974). The skin tends to shrivel with a relatively small loss (4-6%) of water causing fine wrinkling of the cuticle and immediate loss of skin glossiness.

Strawberry fruit quality is affected by many pre- and postharvest enviromental factors. Preharvest factors include both climatic and cultural conditions (Kader 1985). There has been a lot of studies reported to show the effect of light environment on fruits such as apples (Jackson and Palmer 1977a, 1977b; Jackson *et al.* 1977; Seeley *et al.* 1980; Robinson *et al.* 1983; Morgan *et al.* 1984), sweet cherry (Patten and Proebsting 1986) and sweet pepper (Rylski and Spigelman 1986). However, similar work on strawberry is scarce. Furthermore, the limited reports available in the literature are mainly on the effect of sunlight on the ascorbic acid content of strawberry fruit (Hansen and Waldo 1944; McCrory 1946; Ezell *et al.* 1947; Robinson 1949). Moreover, recent studies on the role of light intensity on strawberry perfomance were conducted in grenhouse or controlled environment facilities (Ferree and Stang 1988) Little information exists on the influence of prolonged cloud cover and reduced light levels in the field at various times during the growing season. The objective of this study was to determine the effects of the different levels of preharvest shading, from flowering to harvest, on the physical characteristics associated with postharvest life and quality of primary, secondry and tertiary strawberry fruits.

MATERIALS AND METHODS

Planting Materials and Fruit Source

The experiments were conducted at Wye College, University of London. The strawberry (*Fragaria* × *ananassa* Duchesne) c.v. Ostara plants were transplanted on 10 raised beds. Each bed measured 1700 cm long and 90 cm wide and the distance between beds was 90 cm. The raised beds were covered with white/black PVC mulch, with the white surface on the outside. The plants were arranged in two staggered rows per bed with the distance between plants being 40 x 30 cm. There were 80 plants in each bed. Each primary, secondary and tertiary fruit was labelled at anthesis with a red, white and blue tag respectively. The plants were sprayed with Elavaron (dichlofluanid) at a concentration of 1.34 g per litre every ten days from the appearance of first flower to harvest. (The ripe fruits were harvested 32 ± 2 days after anthesis). Only ripe fruits free from mechanical injury and rots were used in this experiment.

Preharvest Shading

Five levels of preharvest shading (Table 1) were provided by covering the strawberry plants with netting of different levels of light penetration. Shading (level of light penetration) was measured using a light photometer. Measurements were done in triplicates with six observations per replicate. The nettings were held between galvanised steel hoops and wire clips. The three fruit types under these five levels of preharvest shading were further subdivided into above (completely exposed) and below (hidden by leaves) fruits as illustrated in *Fig. 1.*

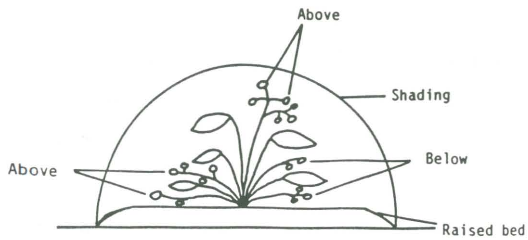

Fig. 1: Schematic diagram to illustrate fruits which are classified as above and below

TABLE 1
Mean percentage light penetration at the different location of fruits and levels of preharvest shading.

Preharvest shading level	Percentage light penetration ± S.E. Location of flower truss Above	Below
S_0 (Control)	73.36 ± 2.85	10.52 ± 0.40
S_1	57.53 ± 2.11	8.00 ± 0.83
S_2	47.64 ± 0.88	6.90 ± 0.79
S_3	38.21 ± 0.39	6.19 ± 0.29
S_4	5.25 ± 0.54	1.00 ± 0.19

S.E. - Standard Error of Mean

Control plots (S_0) were also covered to prevent damage from birds.

The experiment was conducted using randomized split-split plot design with three replications. The five levels of preharvest shading constituted the main plots and the location of fruits as sub-plot with each containing the three different fruit types. Each plot contained 40 plants.

Fruit Weight and Determination of Percentage Moisture Loss

Ten primary, secondary and tertiary fruits from each treatment and replicate were individually weighed after harvest and placed in a plastic punnet. Then the plastic punnets were kept in cardboard trays. Only five fruits were placed in each punnet to avoid any mechanical injury. Then the fruits were stored at ambient conditions (20 ± 1°C), 70 ± 5% relative humidity) for assessment of fruit weight at 2 day intervals. This assessment was terminated after day 6 (six days after harvest) since the fruits suffered either from surface dehydration or softening.

Using the fruit weight at harvest (day 0) and the respective weight at each day of assessment, the percentage of moisture loss was calculated with the following equation:

$$\text{Percentage of moisture loss at day x} = \frac{\text{Weight at (day 0 – day x)}}{\text{weight at day 0}} \times 100$$

Fruit Surface Glossiness

A five point scale was used to evaluate fruit surface glossiness (5 = 100% of fruit surface glossy/shiny, 1 = 0% of fruit surface glossy/shiny).

The same 10 fruits that were used for continuous monitoring of fruit weight were used to score the fruit surface glossiness. Assessment was made at every 2-day intervals. The fruits were given a score of 5 at the beginning of the assessment (Day 0).

Surface glossiness at any day of assessment was expressed as (i) percentage reduction or (ii) percentage retention of glossiness calculated using the following equation:

$$\text{Percentage reduction at day x} = \frac{\text{Log (score) at day 0 – log (score) at day x}}{\text{Log (score) at day 0}} \times 100$$

$$\text{Percentage retention at day x} = \frac{\text{Log (score) at day x}}{\text{Log (score) at day 0}} \times 100$$

Fruit Firmness

Firmness and skin strength of 10 fruits were determined using a Seta 1700 universal penetrometer, fixed with a pointed plunger (0.2 cm in diameter). Each fruit was punctured twice, on opposite sides, with skin intact and twice with skin peeled off. For the later measurement, about 0.1 cm of the skin was peeled off using a razor blade before subjecting the exposed portion to the plunger tip. Fruit wall and flesh strength values were determined by recording the travel speed (the faster the speed, the less firm the fruit) of the plunger through the fruit wall and flesh for five seconds using a constant weight of 50 g. This constant time of five seconds and weight of 50 g were chosen after several preliminary trials. The speed of the plunger (mm s^{-1}) through the fruit was measured by a dial meter attached to the penetrometer.

Percentage Fruit Dry Weight

Ten fruits per treatment per replicate were used for the determination of fruit dry weight. Each individual fruit from each treatment was placed in a sampling bag and dried in the oven at a temperature of 80°C for 48 h until a constant weight was obtained (modified AOAC, 1975). The percentage dry weight was then calculated as below:

$$\text{Percentage dry weight} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

RESULTS

The ANOVA table in Table 2 shows the effect of different levels of preharvest shading, location of fruit, fruit types and storage time (days) and their interactions on fruit weight, percentage of moisture loss, glossiness, fruit firmness and fruit dry weight. All the five quality parameters were significantly ($P < 0.01$) affected by the different levels of preharvest shading. With the exception of percentage moisture loss and fruit firmness (without skin) location of fruits was shown to affect the quality parameters studied. From Table 2, it was also observed that all the parameters studied changed significantly ($P < 0.01$) with storage day and that the different fruit types responded differently.

Fruit Weight and Percentage of Moisture Loss

Fruits shaded by S_4 were significantly smaller than those shaded by S_o, S_1, S_2 and S_3 (Table 3). Results obtained also indicate that location of fruit under these different levels of preharvest shading had an effect on the fresh fruit weight. Fruits that were hidden by the leaves (below) were significantly bigger than those located above the leaves (Table 3).

There was also a significant decrease in fruit weight with storage time. Primary fruits were also found to be significantly bigger than secondary and tertiary fruits.

There was a significant interaction observed between location of fruit and fruit types on fresh fruit weight (*Fig. 2*). *Fig. 2* indicates that location of fruits had a significant effect on the primary and secondary fruits but not on the tertiary fruit for fresh fruit weight.

Correspondingly, the percentage of moisture loss was also significantly affected by the different levels of preharvest shading (Table 2).

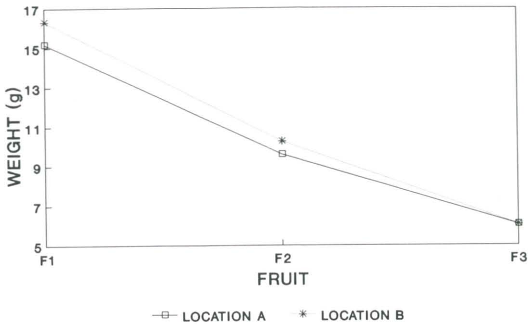

Fig. 2: Interaction between location of fruit (above (A) and below (B)) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3)) on the fresh fruit weight. Values are means of fruits from all types in each location. Trend analysis is provided in Table 2

were also shown to have significantly lost more moisture than secondary and primary fruits respectively. However, location of fruits under the different levels of preharvest shading alone did not have any significant effect on the percentage of moisture loss. Nevertheless, there was a significant interaction between storage time and location of fruits (*Fig. 3a*) on the percentage of moisture loss. There was no difference in the percentage of moisture loss between the hidden (below) and exposed (above) fruits during the first two days of storage. However, on day 4, below (hidden under leaves) fruits were observed to lose significantly more moisture than the above (exposed) fruits. Significant interaction was also observed between levels of preharvest shading

TABLE 2

Mean squares of the analysis of variance of five quality parameters of strawberry fruits as influenced by different levels of preharvest shading.

Main Effect	df	Fruit Weight (g)	Percentage of Moisture Loss (%)	Glossiness (Log score)	Firmness ($mm\ s^{-1}$) ws	Firmness ($mm\ s^{-1}$) wos
Shading (s)	4	429.003***	303.319***	0.1287**	12.4790**	14.4118**
Error a	8	8.080	14.890	0.0033	0.8761	0.9914
Location (L)	1	27.638*	2.137	0.0342*	1.5592**	0.5231
S x L	4	3.686	51.190	0.0033	0.1167	0.0523
Error b	10	3.137	2.627	0.0064	0.1476	0.1378
Day (D)	2	62.291**	7529.895**	3.5878**	4.5437**	5.2486**
S x D	8	0.193**	115.288**	0.0495**	0.5172*	0.2305
L x D	2	0.000	40.533*	0.0090	0.1895	0.1324
S x L x D	8	0.128*	63.472**	0.0377**	0.2053	0.2074
Error c	40	0.055	8.135	0.0041	0.2593	0.2125
Fruit (F)	2	2140.424**	337.183**	0.2694**	21.9413**	33.7260**
S x F	8	36.432**	21.891**	0.0033	0.3468	0.2853
L x F	2	6.782**	0.312	0.0017	0.3921	0.4125
D x F	4	2.126	118.098**	0.0908**	1.7485**	0.7431**
S x L x F	8	1.354	4.335	0.0055**	0.2888	0.1183
S x D x F	16	0.063	13.009*	0.0045**	0.2602	0.2163
L x D x F	4	0.051	6.084	0.0068*	0.1781	0.0512
Error d	130	1.127	6.447	0.0021	0.2192	0.1883
Total	263					

*,** are significant at 5% and 1% levels respectively. WS, WOS are with skin and without skin respectively.

The mean percentage of moisture loss was significantly higher for fruits under S_4 as compared to fruits under the levels of preharvest shading (Table 3).

Fruits were also found to lose significantly more moisture with storage time. There was a two-fold increase in the percentage of moisture loss from day 2 to day 4 (Table 3). Tertiary fruits and fruit types for percentage moisture loss (*Fig. 3b*). Except for fruits under S_3, it was shown that tertiary fruits lost significantly more moisture than the secondary and primary fruits respectively. There was no difference in the percentage moisture loss found between the primary and secondary fruits shaded by S_3.

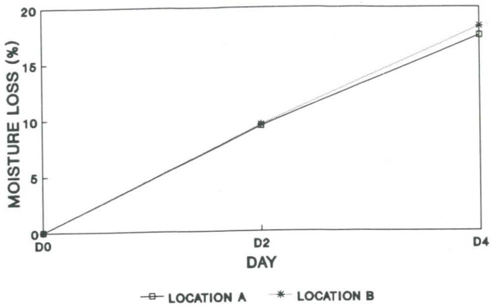

Fig. 3a: Interaction between storage time (Day 0 to Day 4) and location of fruit (above (A) and below (B) on the percentage of moisture loss. Values are means of fruits from both locations on each day of storage. Trend analysis is provided in Table 2

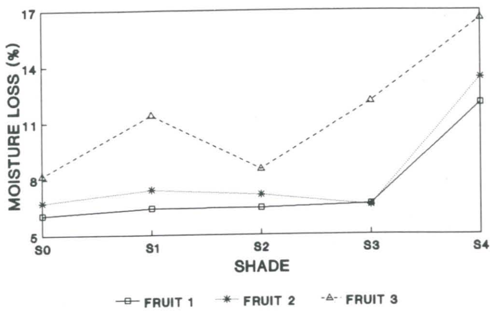

Fig. 3b: Interaction between levels of preharvest shading (S_0 to S_4) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3)) on percentage of moisture loss. Values are means of fruits from all types under each shading level. Trend analysis is provided in Table 2

Fruit Surface Glossiness

The different levels of preharvest shading showed a significant effect on the score of the fruit surface glossiness (Table 2). Fruits shaded by S_3 and S_4 tended to lose their surface glossiness more than those shaded by the other levels of light penetration. Location of the fruits was also found to be one of the determinants of fruit surface glossiness. Fruits which were hidden under the leaves (below) retained their surface glossiness significantly longer than the fruits which were exposed (above).

Fruit surface glossiness was also found to vary with storage time (Table 3). The score decreased by 16 and 54% on day 2 and day 4 respectively. The three fruit types varied significantly in their response to losing surface glossiness . Primary fruit were found to be able to maintain their surface glossiness at a significantly longer rate compared to the secondary and tertiary fruits.

Significant interactions were observed between levels of preharvest shading and storage time (*Fig. 4a*) and between storage and fruit types (*Fig. 4b*). The difference in the ability to retain surface glossiness among the fruits under the different levels of shading increases with increasing storage time (*Fig. 4a*). On day 2, the differences in the surface glossiness between fruits under the different levels of preharvest shading were less apparent as compared to that at day 4. It was found that fruits under S_4 lost the most surface glossiness followed by fruits under S_3, S_0, S_2 and S_1 respectively. *Fig. 4b* indicates that the ability to retain surface glossiness changed with increasing storage time. On day 2, tertiary fruits were observed to retain surface glossiness the least followed by secondary and primary fruits. However, by day 4, tertiary fruits appeared to be able to retain more of their surface glossiness compared to the primary and secondary fruits respectively.

Fruit Firmness

There was a significant effect of preharvest shading on the fruit firmness, whether the skin was intact or removed (Table 2). However, in both cases, the difference was only found to be significant between fruits under S_4 compared to the other preharvest shading levels (Table 3).

Location of fruits under the preharvest shadings significantly affected the fruit firmness only when the skin was intact (Table 3). Fruits located below the leaves were found to be significantly less firm compared to the fruits above the leaves. Nevertheless, in both cases, a significant difference was detected in the mean fruit firmness with storage time. The role of the skin to puncture resistance could be the cause of the differences in the perfomance between the two situations.

The three fruit types also varied significantly in their firmness. Whether the skin was still intact or removed from the fruit, the mean firmness was significantly less in the primary fruits compared to that of the secondary and tertiary fruits. This may possibly be explained by the nature of the fruit diameter (thickness of the cortex) itself at the equatorial region (Osman 1989). When the skin was intact, there was a significant interaction observed between levels

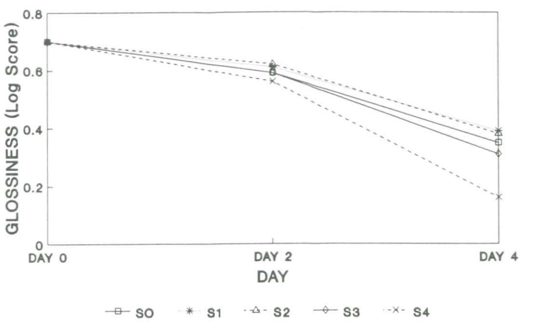

Fig. 4a: Interaction between levels of perharvest shading (S_o to S_4) and storage time (Day 0 to Day 4) on the fruit surface glossiness. Values are means of fruits from all levels of shading on each storage day. Trend analysis is provided in Table 2

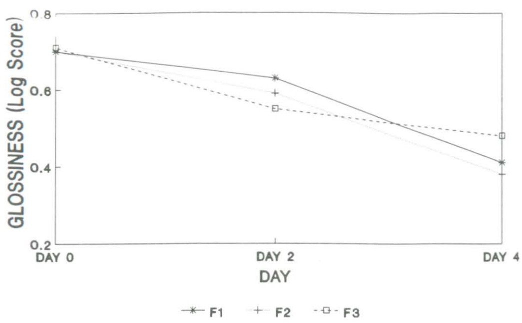

Fig. 4b: Interaction between storage time (Day 0 to Day 4) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3)) on fruit surface glossiness. Values are means of fruits from each day of storage. Trend analysis is provided in Table 2

TABLE 3

Mean values for fruit weight, percentage of moisture loss, glossiness (Log score), firmness (with skin) and firmness (without skin) of strawberry fruits.

Main Effect	Fruit Weight (g)	Percentage of Moisture Loss (%)	Glossiness (Log score)	Firmness ($mm\ s^{-1}$) WS	WOS
Shading (s)					
S_o (Control)	12.36	6.99	0.55	4.46	4.68
S_1	12.27	8.41	0.57	4.53	4.61
S_2	11.75	7.77	0.57	4.51	4.63
S_3	10.88	8.41	0.53	4.34	4.50
S_4	5.57	13.93	0.47	3.48	3.54
$LSD_{0.05}$	1.26	1.62	0.03	0.42	0.44
Location (L)					
A	10.27	8.96	0.51	4.19	4.35
B	10.77	9.26	0.54	4.34	4.42
$LSD_{0.05}$	0.48	NS	0.02	0.10	NS
Day (D)					
0	11.48	0.00	0.70	4.11	4.49
2	10.38	9.46	0.59	4.54	4.55
4	9.68	17.88	0.32	4.15	4.13
$LSD_{0.05}$	0.07	0.86	0.02	0.10	0.14
Fruit (F)					
F_1	15.75	7.51	0.58	4.76	5.04
F_2	9.93	8.24	0.56	4.18	4.28
F_3	6.04	11.59	0.48	3.86	3.85
$LSD_{0.05}$	0.31	0.74	0.01	0.14	0.13
Grand Mean	10.55	9.11	0.54	4.27	4.39

F_1, F_2, F_3 are primary, secondary and tertiary fruits respectively. A, B are above and below (location of fruits) respectively. NS. Not significant. WS, WOS are with skin and without skin respectively.

of preharvest shading and storage time (*Fig. 5*). Throughout the storage time, fruits under S_4 were found to be the most firm compared to fruits under the other preharvest shading levels. For the other preharvest shading levels, fruits under S_0 seemed to be most firm on day 0 but the reverse was true on day 4.

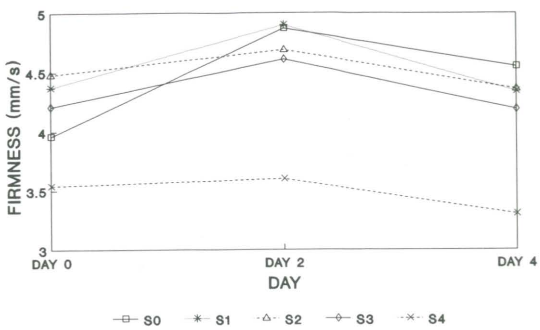

Fig. 5: Interaction between levels of preharvest shading (S_0 to S_4) and storage time (Day 0 to Day 4) on the fruit firmness (with skin). Values are means of fruits from all levels of shading on each storage day. Trend analysis is provided in Table 2

Percentage Fruit Dry Weight

The analysis of variance (Table 4) indicates that the percentage dry weight was significantly affected by the different levels of preharvest shading. The percentage fruit dry weight decreased significantly with the decline in the levels of the percentage light penetration from S_0 to S_4 (Table 5). Although there was an overall decrease in the percentage dry weight, this negative effect was not significantly different between fruits shaded by S_0 and S_1 and between that of S_2 and S_3. A significant difference, however, was observed between the fruit types. Nevertheless, this difference was only significant between primary fruits and other fruit types.

TABLE 4
Mean squares of the analysis of variance of dry weight content (%) of strawberry fruits

Source of variation	df	Dry Weight Content (%)
Shading (S)	4	21.7808**
Error a	8	0.6395
Location (L)	1	0.4285
S x L	4	1.0496
Error b	10	0.3469
Fruit (F)	2	12.3205**
S x F	8	0.8447
L x F	2	0.0517
S x L x F	8	0.4176
Error c	40	0.7034
Total	89	

** significant at 1% level

TABLE 5
Mean values for percentage dry weight of different fruit types of strawberry grown under different levels of preharvest shading.

Main Effect	Fruit Dry Weight (%)
Shading (s)	
So (Control)	6.87
S_1	6.47
S_2	5.78
S_3	5.55
S_4	4.01
$LSD_{0.05}$	0.61
Fruit (F)	
F_1	6.48
F_2	5.39
F_3	5.34
$LSD_{0.05}$	0.44
Grand Mean	5.74

DISCUSSION

The results indicate that the different levels of preharvest shading had a significant effect on the parameters that were being examined. However, this could only be detected between fruits shaded by S_4 and S_3. Nevertheless, for fruit firmness, whether with skin intact or without skin, the effect was only observed to be significant in fruits shaded by S_4. Thus, the effect of preharvest shading could only be detected when flowering plants were subjected to a very low level of light intensity as in the case of S_4. Another general trend found was the significant effect of storage time on the parameters studied. This trend supports the results of an earlier study (Osman 1989).

The relationship between light and fruit quality differ with different fruits and shading conditions. Ferree and Stang (1988) found that 'Earliglow' strawberry fruit size was increased when constantly shaded during fruiting but yield increase was offset by lower fruit number. Rylski and Spigelman (1986) too reported that under shading (12-26%), individual pepper fruit were larger and had a thicker pericarp but there was also a decline in fruit numbers. These are found to be in contrast to the present results. However, although the yield was not recorded in the present study, it was observed that shading the flowering plants with S_4 had a very low yield in fruit number.

In the present study, it was found that there was a significant decrease in mean fresh weight of fruit with declining light penetration when the plants are shaded from the appearance of flowers to harvest. Mean fresh weight of fruits shaded by S_4 was only 45% of that shaded by S_0 This pattern of response was in accordance with other results on studies of apples and cherries. Shading of 'Cox's Orange Pippin apple tree reduced fruit size through reductions of cell size and number of cells per fruit. (Jackson *et al.* 1977). The average apple size of 'Delicious' apple on shaded branches was also found to be smaller than on unshaded branches (Robinson *et al.* 1983). Heinicke (1966) also reported that 'Red Delicious' apple fruits exposed to less than 50% full sunlight were of small size. Shaded (10-15% full sunlight) branches of 'Bing' sweet cherry reduced fruit set from 64 to 50% compared to the unshaded branches (Patten and Proebsting 1986). They also found that fruits from shaded branches were smaller that those from unshaded branches for the first two harvests but in the last two harvests, shaded fruits became larger. In contrast, Ryugo and Intrieri (1972) found that covered sweet cherry fruits were larger than exposed fruits.

Morgan *et al.*(1984), however, pointed out that the position of the apple within the tree was an important determinant of apple size. They found a strong curvilinear relationship between fresh weight and log percentage transmission of photosynthetic photon flux density. In the present study, it is also shown that the mean fresh weight of strawberry fruits hidden below the leaves were significantly bigger than those exposed directly under the preharvest shadings. This could also be possible due to the fact that 'below' fruits having an advantage over the 'above' fruits by having thicker, shorter peduncles and pedicels. Webb (1973) reported that their results, on cvs. Ostara, Redgauntlet, Cambridge Vigour and a number of unnamed breeding selections, indicated that thicker shorter peduncles and pedicels are likely to produce larger berries or a greater weight of ripe fruit on each truss.

Another probable explanation for the results of the present study, where preharvest shading was only demonstrated to be significantly affected in fruits shaded by S_4 and not with the other levels, was the quality of light itself. Using the photon flux density meter, the red : far red ratio could be measured. The difference in this ratio (a measure of light quality) was only obvious in the case of S_4 (Osman 1989). The ratio below the shading was found to be 55% that of the ratio above the shading. This phenomenon was also reported by Seely *et al.* (1980) and Morgan *et al.* (1984). They found that with apples, there was a highly positive correlation of fresh fruit weight with photosynthetic photon flux density.

Temperature has been reported to affect fruit development (Went 1957) . He found that the size of the individual fruit is inversely proportional to the phototemperature whereas the nyctotemperature has no effect. However, in the present study, the air temperature under the different levels of preharvest shading was found to be similar to the outside ambient temperature. Nevertheless, when thermocouples were placed at a depth of 4 mm into the fruit flesh, over a 3-day period, there was no significant difference in flesh temperature obtained (Osman 1989). This may explain the trend in the mean fresh fruit weight shaded by the different levels of preharvest shading.

There was a negative relationship between rate of moisture loss and fruit surface glossiness score with declining light penetration range from S_0 to S_4. This phenomenon is associated with the relationship of declining fruit size with declining light penetration. A major factor in the rate of moisture loss from produce is the surface area to volume ratio of the material (Wills *et al.* 1981). On purely physical grounds, there is a greater loss of evaporation from produce with a high surface area to unit volume ratio. Thus, other factors being equal, a smaller fruit will lose moisture much faster than a larger one. This was found in the present study. Fruits shaded by S_4 (smaller size) lost moisture significantly more rapidly (13.99%) than fruits shaded by S_3, S_2, S_1 and S_0 where the percentage of moisture loss was only 8.41, 7.77, 8.40 and 6.99% respectively.

The fact that primary fruits tend to lose moisture at a less rapid amount compared to the secondary and tertiary fruits found in this study could be due to the same phenomenon.

Correspondingly, in the present study, fruit surface glossiness was found to decrease with a drop in percentage light reaching the flowering plants. However, although a significant effect of different levels of preharvest shading was found on the fruit surface glossiness, this difference could be statistically detected between fruits that were heavily shaded (S_4 and S_3) compared to the other levels of shading. This too could be related to the production of smaller fruits with a decline in percentage light penetration, which in turn led to a higher loss of moisture from the fruit. Skene (1971) reported that the dulling (loss of shine or glossiness) of the fruit surface was due to the shrinkage loss of 4-6%. In the present study, it was found that fruits located below the leaves tend to retain their surface glosssiness more significantly than the fruits which were exposed (only shaded by the preharvest shading).This response is also exhibited by mean fresh weight where fruits which were located below the leaves are bigger.

A negative relationship was also detected between percentage of moisture loss and fruit firmness. Results of the pesent study are in agreement with the finding of other researchers. Smaller fruits tend to be slightly firmer than larger fruits at an equal stage of development. Darow (1931) found that small berries were firmer than medium-sized strawberries. Robinson *et al.* (1983) also showed an increase in apple firmness as the exposure level of canopy was reduced. The inverse relationship between fruit firmness and percentage full sun supports the finding of Heinicke (1966) in his study of 'McIntosh' and 'Red Delicious' apples. However, Seely *et al.* (1980) found no relationship but Smock (1953) found a positive relationship between firmness of 'McIntosh' apples and cumulative solar radiation during the last six weeks of the growing season. Therefore, it is possible that, in the case of apples, the effect of light exposure level on fruit firmness is an indirect one due to the influence or light exposure on fruit size and maturity (Robinson *et al.* 1983).

In the present study, the mean firmness of fruits located below the leaves was found to be significantly less than the above fruits. The results obtained for the fruit firmness could be attributed to the nature of the cortex thickness and method of assessment employed. Hence, in this respect, strawberry fruit firmness could be assessed more quantitatively by using other instruments. For example, it has been shown that toughness of skin and firmness of cortical flesh of strawberries could be measured by the Instron Testing Machine (Ourecky and Bourne 1968). The difference in the internal structure of fruit can be characterised. Using the Instron machine for measurement of strawberry firmness, two to three distinct peaks were produced by the recording system, a strip chart which draws a force-distance curve for each cycle. These peaks indicated the puncture-force required to break through the skin, the nature of the flesh and the total resistance to puncture.

It is concluded that the quality parameters of strawberry fruits such as fresh fruit weight, percentage of moisture loss, surface glossiness and firmness can be affected by preharvest shading but only when subjected to a very low level of light intensity. Location of fruits, different fruit types and most notably storage time also contributed to the changes of fruit quality parameters.

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