Assessment of a netting system for apple production in a Mediterranean semi-arid climate

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Abstract

Photoselective nets were used for protected apple cultivation system in a semi-arid Mediterranean climate in Lebanon. For two seasons, blocks of trees from early bearing and late bearing cultivars were covered with nets in an experimental orchard and compared to uncovered blocks of trees in the same orchard. Microclimate data were monitored throughout the seasons and pests scouting was performed weekly in both treatments. The assessment of the protective netting system covered its impact on tree physiology and production indicators, postharvest fruit quality indicators, microclimate modification and its ability to exclude major insect pests without the use of insecticides. Two years data collection and analysis seems to indicate that the netting system is a promising tool for a better quality fruit in both cultivars and an overall tree health with the opportunity of significantly reducing the need for pesticides.

Keywords: tree fruit production, nets, photoselective, apples, postharvest quality, light stress, codling moth

INTRODUCTION

Netting is being tested around the word in tree fruit production as an efficient way to protect crops against climate challenges i.e., excessive radiation (light and heat), hail, wind, and against biological challenges i.e., flying pests (insects, bats, birds) and to improve quality and yield (Manja and Aoun, 2019). For a recent exhaustive review on the use of nets for tree fruit crops and their impact on the production refer to Manja and Aoun (2019). Thanks to technological advances with photo-selective plastic filters, colored nets have been developed, which provide differential filtration of solar radiation together with physical protection. In plants, including some fruit trees, it has been demonstrated that changes in light composition in red, far-red and blue spectra affects significantly fruit tree plant responses and could be a useful tool for sustainable (e.g., lower use of chemicals and labor-practices) management of yield and quality in modern orchards (Bastías and Grappadelli, 2012). However, the potential use and benefit of this technology in fruit tree production remain under-explored and needs to be optimized depending on the species/cultivar and geographical region.

The aim of this study was to assess the use of red photoselective nets with 20% shading factor and a mesh size of 5.2×2.1 mm in a full block incomplete exclusion system with nets covering entire plots without excluding the soil from the trees under semi-arid Mediterranean climate. A detailed report on the first year experiment is published in a previous article (Aoun and Manja, 2018).

MATERIALS AND METHODS

Trial design and net specifications

The experiment was conducted in a research apple orchard at the American University of Beirut/Advancing Research Enabling Communities (AREC) Center in Lebanon. The apples were planted in 1999 at 4.5×3.5 m spacing. The experiment included two treatments: covered and uncovered trees from 'Jonagold' (early cultivar) and 'Fuji' (late cultivar). Six trees per cultivar were followed for each treatment for a total of 24 trees. The covered trees were randomly dispersed in four blocks with two or four trees per block of both cultivars. The photoselective red nets (N Leno 3640(red) Polysack, Green.tek, Inc., Janesville, WI, USA) with

a 20% shading factor and a mesh size of 5.2×2.1 mm were installed at fruit set in 2017 (May 10) and after petal fall in 2018 (April 18) in a full block incomplete exclusion system and were pulled back at 'Fuji' harvest end of September.

Parameter measurements

Temperature and humidity were measured using sensors (HOBO Pro V2 data logger, Onset, USA) during the whole season. Light intensity was measured using sensors (HOBO Pendant data logger, Onset, USA). Photosynthetically active radiation was determined using a portable light meter (LI-189, LI-COR, USA) at mid-canopy layer.

Measurements of vegetative and reproductive growth were taken in July of both years: the average length of five annual shoots and five clusters per tree respectively were determined. Chlorophyll fluorescent parameters were also assessed using a portable fluorometer (model OS-30p, Opti-Sciences, Hudson, New Hampshire, USA).

Diseases incidence and pests' presence and damage on leaves were assessed once a week on 15 annual shoots per treatment per cultivar. Pests' damages on fruit were also assessed weekly on 15 fruits per tree per cultivar. Traps were set in each treatment to scout codling moth and fruit flies adults.

Fruit harvest was performed on August 29, 2017 and August 20, 2018 for 'Jonagold' trees; and on October 3, 2017 and September 27, 2018 for 'Fuji'. A total of 120 apples per treatment per cultivar were harvested in order to evaluate the apples physicochemical characteristics. The weight and size of each apple were measured using an analytical balance (AB-204 S, Mettler Toledo, Switzerland) and a caliper respectively. The percentage of the red blush surface of the apple skin was assessed subjectively. Apples were sorted based on the size and impurities on the skin according to national standards for apples Libnor, No.477, 2001. Sixty apples per treatment per cultivar were subjected to further assessment. Flesh firmness was measured with fruit pressure tester fixed on a stand and fitted with an 11.3-mm diameter head (mod. FT 327 (3-27lbs), Italy). Solid soluble content was estimated using a digital hand-held pocket refractometer (PAL, Atago Co, Japan). Starch index was determined by performing the starch iodine test and assessed based on Cornell University Chart. The apple titratable acidity was determined using an auto-titrator comprising pH Module 867 (Metrohm, Switzerland).

Statistics

Statistical analysis of the data was performed using SPPS version 24 (IBM corp, Armonk, IL, USA). Shapiro-Wilk test was used to assess the data for normal distribution and Levene's test was used for homogeneity of variances. When the assumptions for normality were not respected, transformations were first applied. If no transformation assumed normality, non-parametric tests were performed including chi-square and Man-Whitney test.

RESULTS AND DISCUSSION

Microclimate and annual growth measurements

Netting reduced PAR radiation by an average of 23% compared to open-field conditions. This result corresponded with the shading factor of the nets used in the experiment (i.e., 20%). The net significantly reduced photosynthetic photon flux density compared to control with the highest difference recorded at 12 pm This shading caused by nets positively affected photochemical efficiency of PSII in leaves as Fv/Fm ratio was significantly higher in leaves of netted trees (0.8±0.001 in both seasons) compared to uncovered control trees (0.78±0.001 in both seasons). According to Retamales et al. (2008), in countries with high levels of radiation, shading nets may decrease stressful conditions during midday hours and protect crops from extreme light levels, avoiding heat stress and photosynthesis inhibition. No differences were recorded in terms of temperature and relative humidity between treatments in both seasons nor between fruit set or annual vegetative growth.

Biotic and abiotic stresses

Powdery mildew (*Podosphaera leucotricha*) was the only observable disease that infected the orchard during May and June of both seasons, but no significant differences were recorded between treatments yet 'Jonagold' was more affected than 'Fuji'. Also, mites (*Tetranychus urticae*), leafminers (*Phyllonorycter* spp.), rosy aphids (*Dysaphis plantaginea*), green aphids (*Aphis pomi*) and woolly aphids (*Eriosoma lanigerum*) were rarely observed in the orchard. However, nets offered satisfactory protection against codling moth (*Cydia pomonella*) in both cultivars and in both seasons (Table 1). In addition, the season cumulative of codling moth adults caught in traps was 3 times higher in the control treatment compared to net during both seasons. Male moths flying between rows and on top of the trees, which is the main location for female calling and prospecting prior to mating; seem to be efficiently excluded by the nets (Sauphanor et al., 2012). Male fruit fly (*Ceratitis capitata*) population caught in yellow trap containing an attract and kill pheromone gel was found 3.5 and 2.5 higher in control compared to net in 2017 and 2018, respectively. However, no fruit flies' damages were observed on fruits. Sunburn and bird fruit damage were observed occasionally in the control on 'Fuji' apples at harvest but not found under nets (Table 2). This suggests a potential for the net to protect against these damages.

Table 1. Number of observed damages on 'Jonagold' and 'Fuji' apples attacked by codling moth throughout the season.

Treatment[a]	Jonagold[b]		Fuji[c]	
	2017	2018	2017	2018
Control	20	24	54	24
Net	8	8	9	1

[a]Differences are significant between treatment in both years for each cultivar.
[b]*n* = 165 observations.
[c]*n* = 210 observations in 2017 and 240 observations in 2018.

Table 2. Sunburn and bird damage found on 'Fuji' apples at harvest.

Treatment	Total apples	Sunburn				Bird damage	
		Count		(%)		Count	(%)
		2017	2018	2017	2018	2017	2017
Control	120	14	23	12	19	5	4.17
Net	120	1	0	0.8	0	0	0

Fruit quality assessment

Nets had a significant positive effect on most of the postharvest quality parameters assessed in this study especially fruit weight, size, and color blush percentage (Tables 3 and 4). This may be the result of less stressful climatic conditions under nets as shown by the chlorophyll fluorescence measurements. These results translate well in the grading of the apples according to commercial official standards.

Apples grown under nets were usually slightly softer under nets (Tables 3 and 4); However, no significant differences were recorded for soluble sugar content and malic acid.

Table 3. Quality assessment of 'Jonagold' apples.

Treatment	Weight (g)		Size (mm)		Red blush (%)		Firmness (lb)	
	2017	2018	2017	2018	2017	2018	2017	2018
Control[a]	133a	132a	67a	67a	24a	59a	10.2a	10.4a
Net[b]	141b	139a	68b	67a	34b	64b	9.5b	9.5a

[a]Mean values. Different letters represent significant differences between treatments per year for each parameter at P<0.05
[b]*n* = 120 apples per treatment except for firmness, *n* = 60.

Table 4. Quality assessment of 'Fuji' apples.

Treatment	Weight (g)		Size (mm)		Red blush (%)		Firmness (lb)	
	2017	2018	2017	2018	2017	2018	2017	2018
Control[a]	125a	97a	66a	60a	32a	50a	11a	11.2a
Net[b]	135b	117b	68b	64b	43b	40b	10b	10.7b

[a]Mean values. Different letters represent significant differences between treatments per year for each parameter at P<0.05
[b]*n* = 120 apples per treatment except for firmness, *n* = 60.

CONCLUSIONS

The shading caused by nets in a semi-arid climate positively affected the photochemical efficiency of photosystem II. In addition, nets significantly protected against codling moth while improving postharvest quality. Apples under net were better graded than apples in control. Hence the need to evaluate the economic feasibility of nets in intensive orchards and to collaborate with the industry to develop locally produced and adapted netting systems.

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