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Reflective Particle Films Affected on, Sunburn, Yield, Mineral Composition and Fruit Maturity of 'Anna' Apple (*Malus domestica*)Trees.

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Abstract: This experiment was conducted during 2008 and 2009 seasons on 10 years old 'Anna' apple cultivar on MM /106 rootstocks grown at Al-Nubaria region, Behira government. Two reflective films (RF) were applied at three concentrations two times, after fruit setting and 4 weeks before commercial harvest date with an air-blast sprayer, and control treatment (without reflective film).The reflective film treatments were 1%, 2% and 3% kaolin clay; 0.5%, 1% and 1.5% Silica gel. Results of this study revealed that reflective films sprayed on apple trees increased significantly the leaf area and level of light reflected from the leaves, while decreased the percentages of fruit sunburn. Also, particle reflective films show high positive leaf and fruit contents of N, Ca and Mg response to RF than trees no RF and reduced with increasing the concentrations of RF. Furthermore, the color response to RF was greatest with reflective film treatments, while not affected on fruit firmness, length and diameter of fruits. Also, the FR seemed to be increased fruit weight as well as yield as compared with no-RF treatment. Generally RF treatments delayed maturation and this appear in decreased TSS, total sugars and the increase in acidity and starch content.

Key words: reflective film, leaf area, sun burn, mineral composition, fruit quality.

INTRODUCTION

One of the primary determinants of the value of many apple cultivars is fruit red color without sunburn. Fruit from trees on more vigorous rootstocks, however, have less sunburn and red color due to the presence of more foliage[48]. Red color of fruit without sunburn requires temperatures more cool. Sunburn and lack of red fruit color reduced pack out especially in drought regions. Foliar sprays of reflecting materials may reduce transpiration in three different ways: reduce the absorption of radiant energy and thereby reduce leaf temperatures and transpiration rates; form thin transparent films which hinder the escape of water vapor from the leaves, and finally prevent stomata from opening fully, thus decreasing the loss of water vapor from the leaf[8]. Plants use several protective mechanisms to avoid sunburn, e.g.,a) dissipation of excess energy through the xanthophylls cycle[10,42], b) induction of antioxidants to minimize oxidative damage[33], c) UV-B attenuation by UV-B-absorbing/reflecting pigments[39] and d) production of heat shock proteins[46].

Although the relative contribution of heat and light stresses to sunburn is not yet clearly established, sunburn is caused by the interaction of high temperature and light[25,47]. Particle film sprays such as kaolin and silica gel have been recommended to lower the temperature of the fruit, thereby reducing sunburn and improving red fruit color[24,26,55].

On the other hand, red skin coloration of apples is directly related to the proportion of red pigmented cells in the skin and the size of the vacuoles containing the anthocyanin pigments[31,28]. Also,[36] reported that, the maximum capacity for anthocyanin synthesis is genetically controlled and the environmental factors interact with the genetic factors. So, horticultural practices can impact fruit appearance and quality at harvest[43]. Reflective films have been used to reflect sunlight from the orchard and improvement the red skin coloration and slight increase in maturity[12,53]. In the climate of Egypt, "Anna" apple trees has tendency not to develop good red color and tented to drop prematurely. Poor coloration has been a serious problem in affecting growers profit from these cultivars. Various measures have been tried to improve

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fruit coloration but few have been successful. Although, ethephon is effective in promotion anthocyanin synthesis[13], it is not effective in late cultivars[7]. Moreover, it was found that increasing light intensity in the tree canopy by providing supplementary illumination significantly improved fruit coloration in apple[2,19]. Covering the orchard of sprays with reflecting films was also effective in increasing light intensity in the tree canopy and improving fruit coloration[41,19]. Laboratory and field trials with fruits treated with the processed kaolin ‘Surround WP’ in nectarines, in apples and in persimmons carried by[37] indicated an almost complete protection against infestations of the Mediterranean fruit fly (medfly), Ceratitis capitata (Wiedemann) (Diptera: Tephritidae). No information has been published on the leaf area, light intensity, mineral composition of leaf and fruit and fruit quality of Anna apple fruits in Egypt under this region.

This study was initiated to evaluate the effect of reflective films on leaf area, light / intensity,sunburn fruit percentages, leaf and fruit mineral composition, yield and fruit quality of "Anna" apple trees.

MATERIALS AND METHODS

Studies were conducted during 2008 and 2009 seasons in private farm on 10 years old ‘Anna’ apple cultivar on MM/106 as a rootstock grown at Al-Nubaria region, Behira governorate. The trees in this experiment planted at 3.5×5m spacing. Specific details concerning the soil analysis are presented in Table (1). Soil samples were, randomly, taken from two depths (0-30 cm and 30-60 cm) prior to initiating of the experiment and analyzed for physical and chemical properties. A randomized complete block experimental design was used in this trial using five trees for each treatment. Thirty five ‘Anna’ apple trees nearly uniform as possible in growth vigor and productivity were chosen for this study. The trees were subjected to fertigation system used in the practical field. Trees were trained to the central leader system. Other cultural practices were applied in a manner consistent with those of commercial ‘Anna’ apple with orchards.

Two reflective films were applied, with three concentrations for each, with an air- blast sprayer and control treatment. Several buffer trees were used to prevent over sprays between sprayed and non-sprayed trees. The reflective films application on the canopy surface of trees as follows:

Control (untreated trees).
1% Kaolin clay.
2% Kaolin clay.
3% Kaolin clay.
0.5% Silica gel.
1% Silica gel.
1.5% Silica gel.

Reflective films were applied after fruit setting and 4 weeks before the first anticipated commercial harvest date using Tween -20 (1%) as a surfactant.

Leaf area was examined by portable area meter LI .COR model LI-3000 A. Light intensity was measured as food candle (F.C) in the central of the trees using Panlux electronic Z apparatus in the different treatments. Fruit sun burinist status was visually estimated as the percentage of sunburned fruit on each tree relative to the total number of fruit on the tree just before harvest[48]. For determining N, Ca and Mg in the fruits and leaves, at harvest time, sample of fruits were washed with tap water and rinsed with distilled water, the fruits were separated and cut into small pieces using a clean knife and each part was mixed well. Also, 30 leaves were collected from each tree from the third leaf on shoots. Leaf samples were washed with tap water, then with distilled water and oven dried at 70C° for 72 hours to a constant weight (fruit and leaf samples). The dried sample of fruits and leaves were ground and digested with sulphoric acid and hydrogen peroxide according to[15]. Suitable aliquots were taken for the determination of mineral elements in leaf and fruit samples. Nitrogen was determined calorimetrically [14]. Calcium and magnesium by Perken Elemer Atomic Absorption Spectrophotometer as described[29].

The mature fruits of each tree were harvested and weighted at late of June in the two seasons. Samples of 10 fruits were taken from each tree for physical and chemical analysis. Yield, Weight, diameter and length of fruits were recorded. Fruit firmness was determined by[34] pressure tester using a 5/16 plunger, two reading were taken on the flesh of each fruit after peeling. Fruit color was visually ranked an a scale for 1 to 5, with 1=20% red progressive, 2=40%, 3=60%, 4=80% and 5=100% red color. Also, anthocyanin content was determined at the stage of coloration (mg/100g fresh weight)[44]. From these ten fruits, two fruits were used for measuring total soluble solids using hand refractometer, acidity and starch content using[3]. Total sugars content was determined according to the the outlined procedures[35]. The starch content was determined in 0.1gm of the residue by hydrolysis with concentrated HCl for 3 hours under reflux condenser[3]. The total reducing power was determined [35], and the factor 0.9 was used to calculate the starch[57]. The obtained data throughout the two studied growing seasons were statistically analyzed using the analysis of variance[50].

Table 1: Soil analysis prior to initiation of the experiment.

Depths (cm)	Sand %	Silt %	Clay %	PH	EC (ds/m)	Anions (meq/L)			Cations (meq/L)				
						HCO_3^-	CL^-	SO_4^-	NH_4^+	Ca^{++}	Mg^+	Na^+	K^+
0 – 30	85.3	2.1	12.6	7.6	5.84	2.9	20.2	8.27	0.06	6.4	8.0	16.7	0.22
30 - 60	86.2	3.1	10.7	7.5	3.02	3.48	8.10	6.57	0.09	4.4	4.0	9.20	0.55

Soil Texture: Sandy loam

RESULTS AND DISCUSSION

Leaf Area: Regarding the effect of spraying “Anna” apple trees with kaolin and silica gel on leaf area, the data presented in Table (2) indicated that, in both experimental seasons, spraying trees with kaolin at 1, 2 and 3% and 0.5% silica gel treatments caused a significant increased in leaf area as compared with untreated trees. Also, the spraying "Anna" apple trees with 1% silica gel did not affect significantly the leaf area, while 1.5% silica gel treatment reduced significantly the leaf area as compared with untreated trees in both seasons. On the other hand, 1% kaolin treatment gave the highest significant value compared with other treatments in both seasons. These results are in antagonist with data showed by different authors who reported that, the application of RF slightly decreased the leaf area because the environmental dusts and particulate coverings generally reduced photosynthesis[17,27] due to leaf shading and interference and reduce transpiration more than photosynthesis at high solar radiation levels. Moreover,[19,23] found that particle film application influences apple leaf physiology and increase foliage reflectivity and reduce heat load on plants with some increase in plant productivity. Film antitranspirants were shown to affect growth adversely by reducing photosynthesis, and favorably by increasing plant water potential[9]. The effect on growth was to: (1) reduce leaf expansion, plant height, and yield of snap beans in the field; (2) increase internodes and leaf elongation of oleanders over a short period, with no effect on shoot length over a longer period; (3) reduce radial expansion of trunks of fruit trees; and (4) increase the size of orchard fruits. Whether an antitranspirant reduces or increases growth of a particular plant part probably depends on whether current photosynthesis or plant water potential is more important to its development at the time of treatment.

Light Intensity: Sunlight had greater light intensity (Food/Candle) at all reflective films applications than light reflected from the untreated trees Table (2). In both experimental seasons, data showed that, the spectral distribution of the reflected light from the 1% kaolin and 0.5% silica gel was more significant than other remained treatments. Also, data mentioned that light reflected from the film was different in quantity within kaolin and silica gel concentrations. It was noticed that, the increment in the concentrations of RF reduced the light intensity in the central of trees. Also, significant differences were found among all RF treatments. This observation is consistent with previous findings[11,1,6,32]. The quality of reflected light from the film was not different from direct sunlight, but it was reduced in intensity[4,12,19]. Reflection of solar radiation by film modified the orchard microclimate[52]. Also, reported that when a reflective film was used with an apple trees, the light absorption by the canopy was increased by 40% in comparison to control[9]. The same conclusion was reported [40].

Fruit Sunburn Percentages: Particle film sprays such as kaolin and silica gel have been recommended to lower the temperature of the fruit, thereby reducing sunburn and improving red fruit color in situation when temperatures are supra optimal[23,26,56]. Data presented in Table (2) are in line with those previous findings. It was found that untreated trees gave the highest percentages of fruit sun burinist, while generally kaolin and silica gel sprays after fruit setting and before the first anticipated reduced the percentages of fruit sunburn. The lowest significant percentage was found with 0.5% silica gel and 1% kaolin treatments in both experimental seasons and the percentage increased significantly by increasing RF concentration, except between 1 and 1.5% silica gel treatments in both seasons. Furthermore, it was reported that, plants use several protective mechanisms to avoid sunburn) dissipation of excess energy through the xanthophylls cycle[10,42] induction of antioxidants to minimize oxidative damage[33] UV-B attenuation by UV-B-absorbing/reflecting pigments[39] and production of heat shock proteins[46]. Sunburn on fruit surfaces occurs under conditions of both high temperature and high irradiance[45,47]. Kaolin reduces fruit surface temperature by increasing the reflection of visible and ultraviolet light[23,58]. The effectiveness of Kaolin in reducing sunburn in most cultivars and regions may be more strongly ascribed to the reduction in harmful radiation reaching the fruit surface than to the reductions in surface temperature[18], although the latter would lower

Table 2: The influence of some reflective films on leaf area, light intensity and sunburn fruit percentage of 'Anna' Apple in 2008 and 2009 seasons.

Treatments	Leaf area (cm^2)		Light / intensity Food / Candle		Fruit sunburn %	
	2008	2009	2008	2009	2008	2009
Kaolin 1 %	38. 2	41.2	23.3	24.9	2.9	3.1
2 %	36.7	35.2	21.3	21.8	4.9	5.2
3 %	36.2	35.2	13.9	18.3	9.2	8.3
Silica gel 0.5 %	37.2	35.7	23.2	27.2	2.1	3.3
1 %	34.2	34.3	16.9	19.2	6.3	7.9
1.5 %	32.3	32.4	15.1	16.1	6.4	8.1
Control	34.2	34.7	9.3	10.2	15.2	16.1
L.S.D 0.05	0.96	0.95	1.25	1.24	1.19	1.20

the threshold for radiation damage. The same results were found by[18,48] on apple. They reported that, kaolin clay particle film produced labeled reduced in sunburn percentages. The same trend was reported by[38] on pomegranate fruits.

Leaf Mineral Contents: The influences of RF treatments on N, Ca and Mg in leaf tissues presented in Table (3) and showed the same trend reported in fruit tissues. It was noticed that the increment in kaolin and silica gel concentrations reduced the leaf contents of N, Ca and Mg. This increment almost not significant in both seasons, except between the two lowest concentrations of both reflective films compared to control in both seasons. The same trend was found[23], they reported that application of particle films increased the foliage reflectivity and influence on leaf physiology.

Fruit Mineral Contents: Effect of spraying reflective film kaolin and silica gel on fruit nitrogen (N), calcium (Ca) and magnesium (Mg) concentrations of 'Anna' apple trees are shown, in Table (4). The data revealed that all reflected films used in this study increased the fruit flesh contents with N, Ca and Mg as compared with control in both seasons understudy. Furthermore, the kaolin 1% or silica gel 0.5% significantly increased the contents of fruit flesh with N, Ca and Mg comparing with control in both seasons, except 0.5% silica gel in the second season for Ca and Mg content. In the meantime, 1% kaolin had a significant value in fruit N content compared to 1.5% silica gel in both seasons. Generally, it was found that increasing the concentrations of kaolin or silica gel decreased the concentrations of N, Ca and Mg contents in fruit flesh in both seasons. These results are in parallel with those obtained by agreement with the obtained others[48,49].

Fruit Physical Parameters: The experiment results presented in Tables (5 and 6) showed that the improvement in yield Kg/tree associated with most of reflective film treatments. Furthermore, it appears from our results that the particle film treatment increased the carrying capacity of apple trees significantly in two concentrations of treatments (1% kaolin and 0.5% silica gel) in both seasons compared to the rest treatments and control. This data agreement with those obtained by[22,23,48,55].

In Amodern study carried out [19] showed that kaolin clay particle films reduced heat stress, increased carbon dioxide assimilation, increased fruit yield and/or size and in same cases, increased red fruit color. Also, they reported that shading caused by particle films decreased net leaves photosynthesis due to reduced total efficiency of stomata conductance and reduced day respiration by 60-70% compared to the control. Spraying the trees with reflective films increased significantly fruit weight in both experimental seasons, except 1.5% silica gel treatment, compared to control in both seasons. This may be due to the application of RF increased photosynthesis[21,23]. The same trend was found about fruit diameter and length in relation to particle reflective film applications compared with those obtained with untreated trees. But no significant difference was found among the treatments. This may be due to reflective film treatments increased the fruit size on trees.

Regarding to the fruit firmness affected by application of reflective film applications, data in Tables (5 and 6) revealed that, the application of RF had no significant effect on apple fruit firmness in both seasons, the same results obtained [48,54]. While fruit firmness was not affected by RF treatments, it was noticed that spraying reflective films resulted in a 40-60% increase in percent red surface of "Anna" apple compared with the

Table 3: The influence of some reflective films on leaf mineral contents of 'Anna' Apple in 2008 and 2009 seasons.

	N (%)		Ca (%)		Mg (%)	
Treatments	2008	2009	2008	2009	2008	2009
Kaolin						
1 %	2.37	2.33	1.30	1.45	0.333	0.361
2 %	2.26	2.22	1.25	1.35	0.321	0.345
3 %	2.25	2.11	1.25	1.37	0.311	0.291
Silica gel						
0.5 %	2.31	2.32	1.31	1.42	0.335	0.351
1 %	2.25	2.26	1.28	1.35	0.324	0.322
1.5 %	2.23	2.22	1.25	1.34	0.315	0.312
Control	2.21	2.19	1.23	1.33	0.302	0.291
L.S.D 0.05	0.10	0.12	0.06	0.07	0.031	0.060

Table 4: The influence of some reflective films on fruit mineral contents of Anna' Apple in 2008 and 2009 seasons.

	N (%)		Ca (%)		Mg (%)	
Treatments	2008	2009	2008	2009	2008	2009
Kaolin						
1 %å	0.34	0.31	0.52	0.54	0.30	0.29
2 %	0.29	0.27	0.48	0.49	0.25	0.28
3 %	0.28	0.26	0.45	0.47	0.24	0.24
Silica gel						
0.5 %	0.31	0.28	0.54	0.51	0.28	0.27
1 %	0.27	0.23	0.48	0.50	0.24	0.26
1.5 %	0.25	0.23	0.47	0.49	0.22	0.21
Control	0.23	0.21	0.41	0.43	0.19	0.20
L.S.D 0.05	0.07	0.06	0.08	0.10	0.09	0.09

Table 5: The influence of some reflective films on some physical properties of 'Anna' Apple fruits in 2008 season.

Treatments	Yield (Kg/tree)	Fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)	Firmness ($lb/inch^2$)	Fruit color* (1 – 5)
Kaolin						
1 %	33.1	120.2	6.37	7.00	9.3	3.8
2 %	29.3	118.9	6.18	6.94	9.0	3.2
3 %	29.0	118.2	6.16	6.89	9.1	2.5
Silica gel						
0.5 %	31.3	118.3	6.17	6.90	9.1	3.7
1 %	29.2	117.6	6.15	6.87	9.3	3.2
1.5 %	29.1	109.2	5.96	6.76	9.2	3.1
Control	28.5	100.6	5.49	6.41	9.1	1.1
L.S.D 0.05	1.5	11.88	n.s	n.s	n.s	0.54

*Color corresponds to visual rating where 1, 2, 3, 4 and 5 represent 0% to 20%, 21% to 40%, 41% to 60%, 61% to 80% and 81% to 100% red surface, respectively.

no-RF control Table (5 and 6) in both experimental seasons. The reddest color was on fruit from trees treated with 1% kaolin clay. Trees treated with 3% kaolin clay only had fruit with the lowest red coloration. Thus, for trees treated with silica gel 1.5% resulted in 60% red surface coloration as compared with untreated trees (about 20% coloration). These results were similar to those reported earlier by[1,12,32,40,41]. Fruit coloration was significant improved by addition of RF, and this may be due to two different ways that light enhances anthocyanin synthesis and accumulation in apples, by increasing canopy photosynthesis and

Table 6: The influence of some reflective films on some physical properties of 'Anna' Apple fruits in 2009 season.

Treatments	Yield (Kg/tree)	Fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)	Firmness (Ib / inch^2)	Fruit color* (1 – 5)
Kaolin						
1 %	30.2	122.9	6.32	7.30	9.1	3.9
2 %	27.5	119.6	6.20	7.13	9.2	3.3
3 %	27.1	117.9	6.18	7.10	9.2	2.4
Silica gel						
0.5 %	30.4	119.7	6.20	7.12	9.3	3.8
1 %	27.3	118.5	6.19	7.11	9.2	3.1
1.5 %	26.6	108.5	6.00	7.00	9.4	3.0
Control	26.5	102.2	6.36	6.76	9.1	1.2
L.S.D 0.05	1.5	11.186	n.s	n.s	n.s	0.540

• Color corresponds to visual rating where 1, 2, 3, 4 and 5 represent 0% to 20%, 21% to 40%, 41% to 60%, 61% to 80% and 81% to 100% red surface, respectively.
* n.s = not significant

Table 7: The influence of some reflective films on some chemical properties of 'Anna' Apple fruits in 2008 and 2009 seasons.

Treatments	Anthocyanin (mg / 100g)		T.S.S (%)		Acidity (%)		Total sugar (%)		Starch (%)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Kaolin										
1%	19.1	20.9	11.9	11.0	0.71	0.70	7.85	7.90	2.64	2.61
2%	18.7	19.4	11.2	11.4	0.70	0.70	7.64	7.71	2.52	2.54
3%	17.5	16.9	11.1	11.2	0.66	0.60	7.58	7.54	2.53	2.55
Silica gel										
0.5%	18.9	20.6	11.8	11.5	0.67	0.62	7.20	7.41	2.64	2.58
1%	18.2	18.4	11.4	12.2	0.63	0.63	7.50	7.43	2.54	2.52
1.5%	18.0	17.3	11.9	11.8	0.63	0.67	7.26	7.30	2.53	2.51
Control	15.0	16.1	12.3	12.0	0.59	0.70	8.10	7.92	2.39	2.45
L.S.D 0.05	3.51	3.21	1.57	1.56	n.s	n.s	0.29	0.29	0.23	0.13

* n.s = not significant

assimilation supply to the fruit, and this indirectly stimulate anthocyanin synthesis by providing substrate. Another possibility is that the films treatment directly stimulated anthocyanin synthesis[30]. In the meantime, improved red colour in some cultivars has also attributed to reduced heat stress, which causes anthocyanin degradation[51].

Fruit Chemical Parameters: To determine whether the reflective films kaolin clay or silica gel sprays correlated with the anthocyanin concentrations, the anthocyanin concentration was improved in the skin and data presented in Table (7). The data showed that, total anthocyanin isolated from apple skin significantly increased with spraying 1 and 2% kaolin clay and 0.5% silica gel compared to control. These results are Replace with: in agreement with[11,16,40,53]. There may be two different ways that light enhances anthocyanin synthesis and accumulation in apples, as shown above. One is to increase canopy photosynthesis and assimilate supply to the fruit, and, thus, indirectly stimulate anthocyanin synthesis by providing substrate. Another possibility is that the film treatments directly stimulated anthocyanin synthesis[30].

Concerning the effects of RF particles spraying after fruit setting and 4 weeks before harvesting on 'Anna' apple trees on fruit maturity, data in Table (7) revealed that, analyses of fruit maturity and internal quality at harvest yielded few significant effects of applications that all R.F treatments significantly decreased TSS and total sugar in both seasons and the lowest value appear in 3% kaolin treatment in TSS, while 1.5% silica gel treatment caused the lowest significant value in total sugar. No significant difference was found among the treatments or compared to control in acidity content, although all treatment decreased the acidity content compared to control. In contrast, RF treatments showed high starch content compared to control and 1% kaolin and 0.5% silica gel caused a significant value compared to control. This supports results reported [5,23,48,54]. They did, however, find evidence of delayed ripening by lower percentage starch conversion at harvest and lower TSS and total sugar. Reduced TSS was probably also related to the larger fruit sizes. We suggest that orchards treated with kaolin and silica gel be individually assessed for optimum maturity and harvest date. Kaolin has been reports of delayed maturation in some trials[23]. Plant tissues contain a range of photoprotective metabolites which reduce damage induced by excess irradiance. These include pigments such as anthocyanins as well as starch content.

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