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Controlling Fruit Physiological Disorders and Improving Productivity of Pomegranate Shrubs by Using Some Nutrients Spraying

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ABSTRACT

The present work was conducted in private orchard located in the northwest of Giza Governorate, Egypt during the seasons of 2022 and 2023 to study the effect of foliar application by using some nutrients calcium chloride ($CaCl_2$), sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) after two and eight weeks from bloom on yield. Fruit cracking, sunburn, yield, fruit quality and physical characteristics were determined. The obtained results showed that all treatments under study decreased the fruit sunburn and cracking percentages and increased the yield of both seasons. Using NaCl proved to be the most effective in enhancing yield. In addition, spraying with NaCl and $NaHCO_3$ treatments enhanced the highest improvement of all chemical properties under study. Also, spraying with NaCl treatment among the other treatments under study and succeeded increasing leaf N, Ca, K, and P as well as increasing seed N, Mn, and Ca as compared with either $CaCl_2$ or $NaHCO_3$. On the other hand, spraying with $CaCl_2$ succeeded in increasing leaf Zn and Mg as well as increasing Fe and P. It can be recommended from results of the present study to consider spraying minerals nutrients during twice of 30 days after fruit set in each season have an efficient an effect on improving characteristics of pomegranate fruit quality.

Keywords: pomegranate, cracking, nutrients, sunburn, yield, fruit quality.

1. Introduction

Pomegranate (*Punica granatum* L.) belonging to punicaceae family, is one of the favorite table fruits grown in tropical and sub-tropical regions. Fruit cracking, sunburn, and poor coloration are major challenges for pomegranate producers, often leading to significant yield losses of 30-50%. The factors contributing to fruit cracking include high evapotranspiration, low relative air humidity, sharp temperature fluctuations, and water imbalances during fruit growth and development (Abdelrahman, 2010). Sunburn typically occurs when a period of cool or mild weather is followed by sudden, hot, sunny conditions.

Biochemical characteristics of the fruit, such as total soluble solids (TSS%), ascorbic acid content (mg/100 ml), anthocyanin levels, and fruit coloration, were positively influenced by specific treatments. For example, spraying *Wonderful* pomegranate trees with 4% chloride and 0.4% zinc sulfate at full bloom and again six weeks later significantly improved these biochemical properties (Abd El-Wahed, 2021). In another study, foliar spraying of *Manfalouty* pomegranate trees twice, in mid-June and August, with 20% calcium chloride ($CaCl_2$) increased fruit weight compared to the control (Badway *et al.,* 2019).

The present investigation was undertaken to study the effect of pre-harvest sprayed of some mineral nutrients such as $CaCl_2$, NaCl and $NaHCO_3$ as a new tool were performed in orchard pomegranate to

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white coat the entire trees with the purpose to prevent or reduce these physiological disorders of Wonderful pomegranate.

2. Materials and Methods

This experiment was conducted during two successive seasons 2022 and 2023 at a private in the north west of Giza Governorate- Egypt. Four years old healthy pomegranate trees (*Punica granatum* L.) cv. Wonderfull, grown on sandy soil with 4X3 m distance (830 shrubs per ha^{-1}) under drip irrigation system.

The soil analysis of the experimental sit was used with physical properties i.e pH 8.48, E.C 0.17 dSm-1, $CaCO_3$ 1.33% and organic matter 0.38%, macronutrients mg/100g as (P 0.26, K 19.0, Ca 325, Mg 12.1 and Na 15.2) and micronutrients ppm as (Fe 3.2, Mn 4.2, Zn 1.16 and Cu 0.12). the selected trees were divided into four different treatments included control. The treatments were arranged as follows:

1- Control (sprayed with water only)
2- Sprayed with calcium chloride ($CaCl_2$)
3- Sprayed with sodium chloride (NaCl)
4- Sprayed with sodium bicarbonate ($NaHCO_3$)

The experiment was designed using a Completely Randomized Block Design (CRBD) with three replicates, each represented by one tree. All treatments were applied as foliar sprays twice time per year two and eight weeks after full bloom. Fruit harvesting took place in mid-September during both seasons of study. The following data was recorded

Physiological disorders:

Fruit sunburn percentage:

At harvest time, the number of fruits per tree for each treatment was recorded, and each fruit was visually assessed for sunburn damage. The severity of damage by sunburn was rated, and the percentage of damaged fruits was calculated relative to the total number of fruits on the tree using the following equation (Hegazi *et al.,* 2014).

$$\textbf{Sunburn \%} = \frac{\text{No. of sunburned fruits}}{\text{Total No. of fruits}} \text{ X } 100$$

Fruit splitting percentage

Splitting fruits were counted individually and splitting percentage was calculated by using the follow equation:

$$\textbf{Splitting \%} = \frac{\text{No. of splitted fruits}}{\text{Total No. of fruits}} \text{ X } 100$$

Fruit sunburn and splitting percentages

Fruits of sunburn and splitting were counted together and its percentage was calculated by using the follow equation:

$$\textbf{Sunburn and splitting \%} = \frac{\text{No. of sunburned and splitted fruits}}{\text{Total No. of fruits}} \text{ X } 100$$

Yield and its Components

In Mid-September of each year (2022 and 2023) at harvesting time, the fruit yield of pomegranate cv. Wanderfull was estimated on basis of number and weight of fruits/shrubs (Kg).

Fruit physical Characteristics

At harvest, samples of fifteen fruits from each tree replicate were selected for analysis of physical characteristics. For each treatment, fifteen fruits from each tree were individually measured, and the average was calculated for each replicate.

- Length (L) (cm) and Diameter (D) (cm) of the fruits were measured using a digital vernier caliper. The length was measured along the polar axis, between the apex and the stem, while the diameter was measured perpendicular to this axis at the fruit's widest point.
- The Fruit Shape Index (L/D) was calculated by dividing the length by the diameter.
- Fruit weight (g), peel weight (g), and grain weight (g) were measured as both fresh and dry weights.

Juice extraction

Ripe fruits were cut open, and the outer skin was removed to access the fleshy sacs that contain the juice. The juice was extracted using a domestic blender and filtered through a cheesecloth. The juice volume (cm^3) was then measured, and the juice's chemical properties were determined.

Fruit chemical characteristics

Total soluble solids percentage (TSS%): Was determined using hand Carl Zeis refractometer. Total acidity (TA%) was estimated as citric acid according to (A.O.A.C,2000). pH juice: was measured using a digital pH meter.

Leaf nutrient concentration

Leaf samples were collected from young shoots, 4 to 7 months old, randomly around the shrub from fully mature leaves during the spring flush then these leaves were treated as follows:

- Washed to remove any contaminants.
- Dried at 70°C until they reached a constant weight.
- Ground into a fine powder and digested to prepare for analysis.

The analysis was conducted to determine the concentration of:

- Macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) (expressed as percentages).
- Micronutrients: Iron (Fe), Zinc (Zn), and Manganese (Mn) (expressed in ppm).
- Leaves and grains were taken for mineral analysis according to Rebbeca, (2004).

Statistical Analysis

The experiment followed a Completely Randomized Block Design (CRBD). The results were statistically analyzed using F-value test to determine the significance of the treatments. Mean comparisons were performed using the Least Significant Difference (LSD) test at a 5% probability level based on the methods of (Snedecor and Cochran (1980). The data were processed and analyzed using the COSTAT program, as outlined by Stem (1991).

3. Results and Discussion

3.1. Fruit sunburn and cracking percentage

The effect of the different treatments on percentages of fruits sunburn, splitting and sunburn with splitting are presented in Table (1). All foliar spray treatments showed a significant decrease in these previous characteristics compared to the control for both study seasons.

Concerning fruits sunburn %, it is clear that sodium biocarbonate had significant decrease in this regard which recorded 19.6 and 20.4 % in the two seasons. While the control treatment gave the highest percentage of fruit sunburns, as it recorded 21.7 and 22.7 % in the 1st and the 2nd seasons. It worth noting, data showed that there were significant differences effect between foliar sprayed of all nutrients in the first seasons. But no significant differ between sodium chloride and calcium chloride in the second seasons.

As for, fruits splitting % it can be noticed foliar spraying with $CaCl_2$ in both seasons significantly decreased in this respect compared with all treatments including control. Followed by spraying with $NaHCO_3$ and NaCl with no differ between them. It's recorded in both seasons.

Regarding fruits sunburn and splitting percentages, data were given the same result in fruits sunburn %. Meanwhile, it showed that slightly differences were observed between treatments, foliar spray with

sodium chloride and calcium chloride in the 1st season as well as sodium chloride and sodium biocarbonate in the 2nd seasons without differences among them.

Table 1: Effect of calcium chloride, sodium chloride and sodium bicarbonate on percentages of fruit sunburn, splitting and sunburn with splitting of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	Sunburn (%)		Splitting (%)		Sunburn with Splitting (%)	
	1st	2nd	1st	2nd	1st	2nd
Control	21.7	22.7	11.7	14.0	10.7	14.3
Calcium chloride	19.7	21.7	9.0	10.3	9.7	12.7
Sodium chloride	19.7	21.3	10.7	12.7	9.0	8.7
Sodium bicarbonate	19.6	20.4	10.0	12.0	6.7	8.7
L.S.D at 0.05	**1.36**	**1.2**	**1.01**	**0.83**	**1.2**	**0.62**

Finally, all treatments decreased the fruit sunburn and spiting percentages of shrubs pomegranate Wonderfull in both seasons as compared with that of the control. The previous positive action of the minerals of sodium biocarbonate and sodium chloride creates a white coating on the tree surfaces that is highly reflective, thus reducing solar radiation reaching the exposed plant surfaces, causing shading of these plant surfaces and redistributes this radiation throughout the plant reaching both leaf surfaces and shaded plant canopy areas reduced canopy temperature (Schupp *et al.,* 2002). In addition, those is useful for fruit control, tree heat stress allevation and improving leaf functioning under drought conditions and thus modify physiological functions (Rosati *et al.,* 2007). The mode of action of calcium in reducing fruit splitting in *Wonderful* pomegranate trees is likely due to its crucial role in strengthening cell walls by forming calcium pectates in the middle lamella. Calcium also stabilizes membrane systems and strengthens bonds between epidermal and other fruit cells. Additionally, calcium helps reduce the formation of the abscission zone between fruits and branches and plays a regulatory role in photosynthesis and protein mechanisms. By enhancing photosynthesis and the formation of plant pigments, calcium improves the quality of the fruit (Ahmed *et al.,* 2011).

These results partially align with findings by Khalil and Aly (2013) and Ahmed et al. (2014) who reported that, cracking fruits in Manfalouty pomegranate cultivar were applying by calcium chloride at 3%. In addition, Hegazi *et al.* (2014) reported that foliar spraying Manfalouty and Wonderfull pomegranate cultivars with $CaCl_2$ decreased percentage of fruit cracking as compared with control. Meanwhile, Abd ElWahed (2021) who reported that cracking fruits, fruit drop and cracking sunburn in Wonderfull pomegranate cultivar were reduced by spraying with calcium chloride at 4%.

Yield and fruit quality

It is clear that form data in Table (2) that spraying pomegranate shrubs with $CaCl_2$ and $NaHCO_3$ as well as NaCl significantly increasing number of fruit/shrub as compared with the control in both seasons of study except in case shrub spraying with $NaHCO_3$ in the first season. However, all minerals spraying were significantly increased of fruit weight (g) as compared with the control in both seasons. In addition, using all nutrients especially $Cacl_2$ was proved to be the most effective in enhancing yield kg/shrub which succeeded increasing up to yield significantly among the other used treatments including control of both seasons.

Physical characteristics

It is clear from Table (3) that spraying pomegranate shrubs with all treatments were significantly increased fruit length (cm) as compared with the control except treated with $CaCl_2$ in the first season. Meanwhile, spraying with all nutrients significantly increased fruit diameter (cm) as compared with the control in both seasons of study except of spraying NaCl in the second season. In addition, spraying with all minerals in both seasons significantly increased fruit shape index as compared with control. Generally, the above results cleared that, spraying with all nutrient treatments enhanced the highest improvement of most physical properties under study.

Table 2: Effect of calcium chloride, sodium chloride and sodium bicarbonate on number of fruit / shrub, fruit weight (g) and yield (kg/shrub) of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	No. of fruit/ shrub		Fruit weight (g)		Yield (kg/Shrub)	
	1st	2nd	1st	2nd	1st	2nd
Control	40.6	43.4	369.3	346.3	15.0	15.0
Calcium chloride	47.0	50.3	369.7	402.0	17.4	20.2
Sodium chloride	41.0	43.0	408.3	439.3	16.7	19.2
Sodium bicarbonate	39.3	45.0	406.7	436.0	16.0	19.6
L.S.D at 0.05	**4.8**	**1.0**	**11.5**	**16.2**	**0.79**	**0.51**

Table 3: Effect of calcium chloride, sodium chloride and sodium bicarbonate on fruit length (cm), fruit diameter (cm) and fruit shape index (L/D) of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	Fruit length (cm)		Fruit diameter (cm)		Fruit shape index (L/D)	
	1st	2nd	1st	2nd	1st	2nd
Control	11.0	11.0	11.7	12.3	0.94	0.89
Calcium chloride	10.7	11.3	12.7	13.3	0.84	0.84
Sodium chloride	11.3	11.8	12.0	12.0	0.95	0.99
Sodium bicarbonate	11.7	11.7	12.2	12.7	0.96	0.91
L.S.D at 0.05	**0.12**	**0.19**	**0.16**	**0.16**	**0.02**	**0.02**

Table (4) demonstrate that all spraying with $CaCl_2$, NaCl and $NaHCO_3$ significantly increased with fruit fresh weight in the first season and $CaCl_2$ in the second season as well as arils fruit weight in both seasons. Meanwhile, spraying with $NaHCO_3$ in both seasons significantly decreased in peel fruit weight as compared with the other used treatments and the control.

Table 4: Effect of calcium chloride, sodium chloride and sodium bicarbonate on fresh weight (F.W) of fruit, peel and grains of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	Fruit F.W		Peel F.W		Grains F.W	
	1st	2nd	1st	2nd	1st	2nd
Control	229.8	237.2	97.0	104.2	136.2	140.7
Calcium chloride	382.5	405.2	187.5	198.6	195.0	206.3
Sodium chloride	259.8	269.5	105.7	109.3	190.1	195.8
Sodium bicarbonate	254.8	270.0	76.3	80.8	178.5	189.1
L.S.D at 0.05	**22.5**	**43.6**	**9.1**	**18.2**	**13.7**	**26.9**

It is clear from Table (5) that spraying pomegranate trees with $CaCl_2$, NaCl and $NaHCO_3$ significantly increased in fruit dry weight in the two seasons as compared with the control. It is worth mentioned, foliar spraying with $CaCl_2$ showed a significant superiority in increasing the dry weight of both fruit and peel in the two seasons of the study compared to other treatments including the control. Regarding grains dry weight, we found that the spraying with $CaCl_2$ significantly increased in the 2nd seasons as compared with the other used treatments and the control. Meanwhile, spraying with $NaHCO_3$ in the 1st seasons significantly increased in grain dry weight as compared with the other used treatments and the control.

Generally, spraying with $CaCl_2$ is the most effective in enhancing yield kg/shrub as compared with the other used treatments and the control of both seasons. As well as the spraying with NaCl came next in this respect in the 2nd season only. Meanwhile, the spraying with $CaCl_2$ treatments enhanced the highest improvement of most physical properties under study. These results partially agreed with the findings of Sheikh and Manyula (2012) obtained highest percentage of yield kg/ tree in pomegranate cultivars "Ganesh" with spraying by $CaCl_2$ at 1% at pre-harvest as compared with the control. In

addition Bakeer (2016) found that foliar application of Manfalouty pomegranate trees suggested that application of $CaCl_2$ 2% at four time (the first week of March,May,July and September) of Manfalouty pomegranate trees increased number of leaves, plant canopy, plant height (cm) and leaf area (cm^2) as compared with the control. Also, Sutanu *et al.* (2017) found that the highest shoot length was obtained when foliar application of Ca at 3%+B at 0.25% in *Punica granatum L* Ca at 3% + B at 0.25% .Meanwhile, Badawy *et al.* (2019) found that spraying of Manfalouty pomegranate trees at twice on mid of June and August with $CaCl_2$ at 2% increased fruit weight (g) as compared with control. However, Elakkad *et al.* (2016) reported that foliar spraying of Manfalouty pomegranate trees with $CaCl_2$ at 80 mg/l at two months after fruit set increased fruit diameter and fruit height (cm) as compared with control.

Table 5: Effect of calcium chloride, sodium chloride and sodium bicarbonate on dry weight (D.W) of fruit, peel and grains of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	Fruit D.W		Peel D.W		Grains D.W	
	1st	2nd	1st	2nd	1st	2nd
Control	68.9	77.1	43.2	45.6	25.7	26.1
Calcium chloride	103.8	131.6	71.1	86.9	32.7	38.3
Sodium chloride	85.4	86.2	49.8	47.8	35.7	36.4
Sodium bicarbonate	75.8	87.7	40.0	35.3	35.9	35.1
L.S.D at 0.05	**6.2**	**14.6**	**7.7**	**8.0**	**2.7**	**5.0**

3.2. Fruit Chemical characteristics

Data in Table (6) indicated that both spraying of $CaCl_2$ and $NaHCO_3$ in both seasons gave fruit with significant higher values of TSS % and juice volume than in the other used in this study of both seasons. Meanwhile, spraying pomegranate trees in both seasons with $NaHCO_3$ and control treatments gave the lowest significant values of acidity as compared with that of the other used treatments which recorded the highest significant acidity percent in both seasons. However, both spraying of $CaCl_2$ and $NaHCO_3$ in the second season gave fruits with significant higher values of juice pH than that in the other treatments including control used in both seasons.

Generally, the above results demonstrated that, spraying with$CaCl_2$ and $NaHCO_3$ treatments enhanced the highest improvement of all chemical properties under study. These results partially agreed with the findings of Elakkad *et al.* (2016) who showed that chemical characteristic of Manfalouty pomegranate trees recorded significantly lower fruit total acidity when trees were sprayed with $CaCl_2$ at 80 ml/L at two months after fruit set. In addition, Badawy *et al.* (2019) found that chemical characteristic of Manfalouty pomegranate trees recorded significant increased fruit TSS % and decreased total acidity when trees were sprayed with $CaCl_2$ at 2% twice.On the other hand, Abdelrhman *et al.* (2017) who found that chemical characteristic Manfalouty pomegranate trees recorded significantly increased fruit TSS% and decreased total acidity as compared with control when trees were sprayed with $ZnSO_4$ at 10g/L at the first week of March, May and June.

Table 6: Effect of calcium chloride, sodium chloride and sodium bicarbonate on fruit chemical properties of shrubs pomegranate "Wonderfull" during the two seasons

Treatments	TSS (%)		TA (%)		Juice pH		Juice volume (cm^3)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	11.00	11.23	1.7	1.8	4.01	4.09	155	160
Calcium chloride	13.53	13.77	2.3	2.4	3.71	3.71	170	180
Sodium chloride	11.27	11.53	2.3	2.4	3.81	3.81	160	165
Sodium bicarbonate	13.63	13.85	1.8	1.9	3.69	3.69	175	185
L.S.D at 0.05	**0.99**	**0.42**	**0.33**	**0.22**	**0.08**	**0.21**	**9.6**	**9.6**

3.3. Leaf and grains minerals content

It is clear from Table (7 a, b) that spraying of NaCl treatment succeeded an increasing leaf N, P and K significantly with those of other spraying treatments and the control in both seasons. Meanwhile, spraying with NaCl in the first season and $NaHCo_3$ in the second season significantly increased leaf Ca as compared with those of the other treatments and the control. However, both spraying with $CaCl_2$ in the first season and $NaHCO_3$ in the second season as well spraying with $CaCl_2$ in both seasons significantly gave the highest concentrations of leaf Zn and Mn as compared with those of the remaining treatments. While, spraying with $NaHCO_3$ gave highest significant concentrations of leaf Mg and Fe in both seasons.

Table 7-a: Effect of calcium chloride, sodium chloride and sodium bicarbonate on macronutrients content of pomegranate leaves "Wonderfull" during the two seasons

Treatments	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	1.32	1.4	0.03	0.04	0.97	1.03	1.92	2.04	75	79
Calcium chloride	1.71	1.82	0.23	0.25	0.87	0.92	2.23	2.37	106	113
Sodium chloride	1.74	1.85	0.26	0.27	1.00	1.06	2.67	2.83	100	107
Sodium bicarbonate	1.68	1.78	0.24	0.25	0.90	0.95	2.43	2.58	118	125
L.S.D at 0.05	**0.02**	**0.01**	**0.01**	**0.001**	**0.001**	**0.001**	**0.03**	**0.02**	**2.8**	**1.1**

Table 7-b: Effect of calcium chloride, sodium chloride and sodium bicarbonate on micronutrients content of pomegranate leaves "Wonderfull" during the two seasons

Treatments	Fe (ppm)		Zn (ppm)		Mn (ppm)	
	1st	2nd	1st	2nd	1st	2nd
Control	133	141	124	131	96	102
Calcium chloride	144	153	221	234	231	245
Sodium chloride	183	194	179	190	183	194
Sodium bicarbonate	230	244	159	168	224	237
L.S.D at 0.05	**5.0**	**2.8**	**3.8**	**2.2**	**6.4**	**4.3**

A glance in Table (8 a, b) indicated that spraying treatment with NaCl gave the highest significant percentage of N and Ca content of grains as compared with that of the other treatments and the control of both seasons. Also, spraying with $CaCl_2$ significantly increased grains P, Fe and Mn contents in both seasons. While, spraying with $NaHCO_3$ gave the highest significant concentrations of grains K, Mg and Zn contents in both seasons. However, both spraying with NaCl significantly gave the highest concentrations of grains Ca content as compared with that of the remaining treatments in both seasons.

Table 8-a: Effect of calcium chloride, sodium chloride and sodium bicarbonate on macronutrients content of pomegranate grains "Wonderfull" during the two seasons

Treatments	N(%)		P(%)		K(%)		Ca(%)		Mg(%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	1.15	1.22	0.101	0.108	2.82	2.99	1.95	2.07	0.15	0.16
Calcium chloride	1.22	1.29	0.135	0.144	2.92	3.1	2.1	2.23	0.20	0.21
Sodium chloride	1.49	1.58	0.124	0.132	2.82	2.99	2.15	2.28	0.21	0.22
Sodium bicarbonate	1.2	1.27	0.076	0.081	3.02	3.21	2.0	2.12	0.23	0.24
L.S.D at 0.05	**0.02**	**0.001**	**0.001**	**0.001**	**0.01**	**0.001**	**0.01**	**0.001**	**0.001**	**0.001**

Table 8-b: Effect of calcium chloride, sodium chloride and sodium bicarbonate on micronutrients content of pomegranate grains "Wonderfull" during the two seasons

Treatments	Fe(ppm)		Zn(ppm)		Mn(ppm)	
	1st	2nd	1st	2nd	1st	2nd
Control	201	213	117	125	26	28
Calcium chloride	252	267	126	133	31	33
Sodium chloride	165	175	127	134	30	32
Sodium bicarbonate	133	141	128	136	29	31
L.S.D at 0.05	**5.0**	**3.0**	**1.1**	**1.13**	**n.s**	**1.13**

Generally, spraying with all nutrients under study succeeded in increasing macro and micro elements of leaves and grains as compared with spraying with the control treatment. These results are in general agreed with the findings of Carl and Emrish (1991) and Dawod and Acad (2023) they found that positive effect of calcium increased leaf calcium content and these increasing may due to the role of that plays are important role in reducing cell membrane on pomegranate. In addition, the positive roles of calcium in enhancing cell division in the plants and building blocks in the synthesis of protein and amino plasma in the main source of nitrogen (Marchaner 2002).

4. Conclusion

It can be concluded that the nutrient shows interesting potential, as a coating to reflect UVA radiation strongly, as well as being an effect and cost effective way to shield fruit from sunburn and splitting damage. Furthermore, it's could have a significant impact on crop production practices in future which could lead to reduced pesticide usage and improved yields.

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