

MINIMIZING THE TRANSPLANT DECAY DEVELOPMENT VIA CA APPLICATION AND MODIFIED ATMOSPHERE INCREASED STRAWBERRY YIELD

[32]

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ABSTRACT

This study was carried out at the Strawberry Improvement Center Experimental Farm, Nobaria, Beheira Governorate and the Horticulture Research Station, Barage, Kalubia Governorate during 2001/2002 and 2002/2003 seasons. The study aimed to investigate the effect of calcium nutrition (0, 13 and 26 kg/fed. Ca) and modified atmosphere storage (10, 20, 30 and 40% CO₂) on the post harvest decay of cold stored strawberry transplants and their subsequent fruit production. The results indicated that increasing the rate of calcium application during the transplant growth period and carbon dioxide concentration around transplants during the cold storage resulted in significant decrements in transplant decay, infection percentage, disease severity of roots and crowns. There was a positive relationship between calcium nutrition and early yield. Moreover, the highest calcium rate gave the highest total yield while no significant difference was noticed between control and 13 kg/fed treatments. This study concluded that adding Ca⁺⁺ at 26 Kg /fed as fertigation of calcium nitrate (13% Ca) to the growing strawberry transplants followed by modified atmosphere storage (40% CO₂) during the prolonged cold storage allowed maintenance of transplant quality and increased their yield while minimizing decay development.

Key words: *Fragaria* transplants, Calcium, Modified atmosphere, CO₂, Decay, Yield.

INTRODUCTION

Due to the expansion of strawberry nursery cultivation, transplant production has become an important industry in Egypt. Increasing the production of high quality transplants per feddan is very desirable by strawberry nursery men.

According to the ministry of agriculture statistics, decay percent of the cold-

stored transplants reaches 18-20% yearly caused by some botrytis, rhizopus and rhizoctonia fungus that develop during the eight months of cold storage period. **Hugh *et al* (1977)** concluded that *Botrytis cinerea* and *Rhizopus Spp* caused fruit rot of strawberry. Because of the nursery growing season is characterized by long periods of leaf wetness and mild temperature, botrytis infects petals, stamens, and

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other floral parts as reported by **Powelson (1960) and Bristow and William (1986)**. **Legard et al (2000)** found that there were significant differences among cultivars in their susceptibility to Botrytis rot; Sweet Charlie was very susceptible as compared with Rosa Linda and Camarosa. Botrytis infects flowers initiated on the transplants near the end of the nursery period, i.e., October, November and December (short day time) before digging out the transplants from the nursery, and it can grow under -2°C (**Mertely et al 2000**). Carbon dioxide increased firmness of fruit tissue, which reduced the decay infection (**Larsen & Watkins, 1995 and Numes & Morais, 2002**).

As for the best percent of O_2 and CO_2 to control mold and to increase field survival, **Lockhart and Eaves (1966)** showed that for transplants which had been stored in controlled atmospheres, these percentages varied from 2.5 to 10.0 % CO_2 and from 2.5% to 12.0% O_2 . On the other hand, **John (1970)** indicated that no effect on mold development was noticed between high and low levels of CO_2 . Moreover, **Lieten and Goffings (1997)** indicated that the combination of low O_2 (2.5%) and high CO_2 (1.5%) atmosphere reduced plant survival, vigour and yield. The effect of postharvest plant pathogens of controlled atmospheres (CA) enriched with carbon monoxide (CO) at 9% was studied by **EL-Goorani and Sommer (1979)**. They found that the suppression of strawberry postharvest plant pathogenic fungi was increased by CO_2 (5-18%) added to the low O_2 + CO atmosphere.

Calcium application increased also plant and fruit calcium content and reduced fungal infection (**Garcia et al 1996**). Modified atmosphere storage sup-

presses fungal growth of Botrytis and Rhizopus in fruits. Therefore, this study aimed to investigate the effect of calcium application and modified atmosphere on the decay and subsequent fruit production of cold stored strawberry transplants.

MATERIAL AND METHODS

This study was carried out at the Strawberry Improvement center Farm, Noubaria, for transplant production and Barrage Horticulture Research Station for fruit production during the two successive seasons of 2001 / 2002, and 2002 / 2003. Uniform Sweet Charlie Super Elite strawberry transplants (first generation from *in vitro* culture plants) were taken from the screen-house at the beginning of January and kept in cold storage at -1°C for chilling requirements until transplanting in the nursery. The sandy soil of the nursery was fumigated with methyl bromide (60 g/ m^2) 15 days before planting. Nursery planting dates were April 14 and 19 in the two tested seasons, respectively. The Super Elite transplants were dipped in 0.1% Benlate solution for 20 minutes then planted at $1.5 \times 1.5\text{ m}$ in plots of 25 m^2 . Calcium nitrate with three rates, i.e., control (without calcium), 100 and 200 kg (13% ca) were applied during September, October and November months as fertigation. Complete randomized design with four replicates was used for calcium treatments. Recommended irrigation, fertilization, and pest control programs for the strawberry nurseries were followed. On January 20, representative random transplants were taken to determine number of leaves and roots, crown diameter, and calcium content of roots and crowns. Transplant diameter was measured by Vernier Caliber. Root and

crown calcium contents were determined according to the method in **AOAC (1975)**. Decay percent was calculated as number of transplants with non sprouted crown buds, dried transplant, brown and black crown transplant and those of deteriorated tissues in one hundred transplants. All these types of transplants should be discarded before transplanting while they are usually unmarketable.

Transplants of each experimental plot were dug out from the nursery then leaves were removed and transplants were packed in plastic bags and put in cartons of 54x 29x 25 cm. The cartons were stored at -1°C and 87-90 RH% and subjected to modified atmosphere with five CO₂ concentrations, i.e., 0, 10, 20, 30 and 40 % as the method of **Sobrisky (1999)**. Fifteen treatments were then tested, i.e., three calcium rates and five CO₂ concentrations in 3X5 factor arrangement in RCB design. Four cartons each has 1500 transplants were used for each concentration and calcium rate.

After cold storage, transplants from the above mentioned fifteen treatments were planted at Barrage Horticulture Research Station in four-row raised bed system with 120 cm width and 40 cm height. Plant distances were 25 cm apart. Planting dates were September 13 and 3 in the two tested seasons, respectively Complete randomized block design with four replicates was adopted. The plot area was 30.6 m² (three rows, each of 6m length and 1.7 m width). All replicates received similar agricultural practices as regards cultivation, fertilization, irrigation, pest and disease control as commonly followed in the district. The soil texture was clay with pH of 7.1 and Ec of 1.06. Random samples of ten plants from each experimental plot were taken after

90 days from planting and fresh weight of leaves were calculated. Early yield was determined as weight of the first seven harvests from each experimental plot. All harvested fruits collected from each plot all over the season were weighed and total yield per feddan was then calculated.

The Fusarium was identified according to **Booth (1971)** and modified by **Nelson *et al* (1983)**. Percentage of infection was calculated as number of infected roots in one hundred roots. Disease severity was estimated according to the formula of **Horsfall and Barratt (1945)**. All percentages were transformed to absolute numbers for statistical analysis according to **Fisher and Yates (1948)**. All obtained data were statistically analyzed according to **Waller and Duncan (1969)**.

RESULTS AND DISCUSSION

1-Effect of calcium application on some transplant characteristics

Data in Table (1) show that no significant effects were noticed for calcium application on the number of leaves per transplant, the number of roots and crown diameter in the two tested years except for the number of roots in the second season.

As for calcium content, the application of calcium nitrate increased calcium accumulation in the transplant crown. Similar results were found by **Garcia *et al.* (1996)**. The high calcium nitrate level decreased calcium contents in the roots in the first season while no significant differences were noticed in the second season.

Table 1. Effect of calcium application on some transplant characteristics before Cold Storage.

Calcium Ca (kg/fed)	Leaf No.	Root No.	Crown diameter (cm.)	Ca % in roots	Ca % in crowns
Control (0)	4.60 a	26.27 a	0.74 a	2.55 a	1.46 c
13	4.25 a	27.47 a	0.82 a	2.50 a	2.68 b
26	4.39 a	27.66 a	0.70 a	2.00 b	3.61 a
2002/2003					
39 Control (0)	4.70 a	23.04 b	0.70 a	2.49 a	1.63 c
13	4.40 a	26.93 a	0.87 a	2.35 a	2.75 b
26	4.03 a	27.43 a	0.73 a	2.46 a	3.12 a

Values followed by the same letter (s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

2- Effect of calcium applications on postharvest pathogens of strawberry transplants before cold storage

In Table (2), data show that the number of pathogens (fungus) and their frequency percent decreased in roots and crowns by using calcium nutrition. Moreover, they decreased also as calcium rate increased. Results show also that five different pathogens were isolated from control plants while only three were isolated from plants received 13 kg/fed of Ca. When plants were treated with Ca at 26 kg/fed, only *Rhizoctonia solani* was found in both seasons and *Botrytis cinerea* was found in the second season. Similar results were found by Garcia *et al* (1996) and Mertely *et al* (2000).

3- Effect of calcium application on infection percent and disease severity in roots and crowns of strawberry transplants before storage

Data in Table (3) indicate that the infection percent and disease severity in the roots and crowns before storage decreased significantly as calcium applications increased in the two experimental seasons. These results may be due to the role of calcium in tissue hardness. Similar findings were reported by Garcia *et al* (1996) .

4- Effect of calcium application and CO₂% during storage on decay Percentage of transplant

The decay percentage of transplants decreased by increasing either calcium

Table 2. Effect of calcium application on postharvest pathogens of Strawberry transplants before cold storage.

Calcium kg/fed.Ca	Isolated fungi	Frequency %	Frequency%
		2001-2002	2002-2003
Control (0)	<i>Rhizoctonia solani</i> (Roots)	10	20
	<i>Rhizoctonia fragaria</i> (Roots & crowns)	13 18	15 8
	<i>Botrytis cinerea</i> (Crowns)	4	5
	<i>Fusarium solani</i> (Roots)	3	2
	<i>Macrophomina phascolini</i> (crowns)		
13	<i>Rhizoctonia solani</i> (Roots)	8	9
	<i>Fusarium moniliforme</i> (Roots)	3	5
	<i>Pythium ultimum</i> (Roots)	2	2
26	<i>Rhizoctonia solani</i> (Roots)	5	4
	<i>Botrytis cinerea</i> (crowns)	--	5

Table 3. Effect of calcium application and modified atmosphere on infection Percent and disease severity in roots and crowns of strawberry Transplants before storage.

Calcium Kg/fed. Ca	Roots		Crowns	
	2001/2002			
	Infection %	Disease severely	Infection %	Disease severely
Control (0)	20.00 a	13.66 a	9.66 a	6.40 a
13	8.33 b	5.33 b	3.50 b	2.30 b
26	5.33 c	3.93 c	0.23 c	0.00 c
2002 /2003				
Control (0)	18.00 a	12.50 a	10.00 a	6.20 a
13	8.00 b	5.10 b	4.00 b	2.66 b
26	6.00 c	4.20 b	0.00 c	0.10 c

Values followed by the same letter(s) do not significantly differ from each other according To Duncan's multiple range test at 5% level. .

rate during the transplant production or CO₂ concentrations around the transplants during the cold storage in the two tested seasons (Table 4). The interaction showed that the highest decay percentage was found in transplants, which was not treated with calcium and stored at normal cold storage conditions. On the other hand, the lowest decay percentage was obtained when transplants were treated with 26 kg/fed of calcium and stored under 40%CO₂ conditions in both years. This may be attributed to increasing calcium content in transplant crowns as found in Table (1) which might decrease the deterioration of transplants, as one of the major decay problems during cold storage and decreasing the fungal growth around transplants by high CO₂%, as reported by **Lockhart & Eaves (1966)**;

El-Goorani & Sommer (1979); **Larsen and Watkins (1995)** and **Numes & Morais (2002)** .

5-Effect of calcium application and CO₂% on the infection percent and disease severity after cold storage

Data in Table (5) indicate that increasing calcium application for the grown transplants as well as CO₂ concentrations around the transplants during cold storage resulted in significant reductions in infection percent and disease severity of roots and crowns after the cold storage period in the two tested seasons. The interaction between Ca applications and CO₂% showed that the highest infection percent and disease

Table 4. Effect of calcium application during transplant growth and CO₂ % during cold storage on decay percentage of strawberry transplants.

Calcium (kg/fed)	CO ₂ (%)					Mean
	2001/ 2002					
	0	10	20	30	40	
Control (0)	32.73 a	16.09 d	11.50 f	9.90 g	4.47 i	14.94A
13	25.33 b	15.09 de	8.04 h	4.03 i	1.92 j	10.88B
26	23.73 c	14.23 e	10.80 fg	2.47 j	0.23 k	10.29C
Mean	27.26 A	15.14 B	10.12 C	5.47D	2.21E	
2002 / 2003						
Control (0)	21.97 a	15.07 b	13.27 bc	11.20cd	6.98 fe	13.70 A
13	20.32 a	14.71 b	8.70 de	2.78 gh	2.66 gh	9.89 B
26	13.00 bc	9.99 d	5.67 fg	1.77 h	0.11 h	6.11 C
Mean	18.43 A	13.25 B	9.31 C	5.25 D	3.25 E	

Values followed by the same capital letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level. mall letters for interaction.

severity in roots and crowns of that were not fertilized with Ca and stored at normal cold storage conditions. calcium concentration (26kg fed) and cold stored at 40%CO₂.

6- Early and total yield

Either calcium fertilization for the growing transplants or CO₂ during the cold storage of transplants had significant effects on early and total yield in both tested seasons (Tables 6 & 7). Early and total yield increased as calcium applications or CO₂ increased. As for the interaction effects, results showed that the highest early and total yields were obtained from plants produced from transplants treated with the high calcium

transplants were obtained from plants On the other hand, the lowest values were recorded for those treated with high rate (26 kg/fed) then stored at 40% CO₂ conditions. On the other side, the lowest values were found in plants grown from transplants which did not receive calcium nitrate then stored at normal cold storage conditions .The results did not agree with those of **Lieten and Goffings (1997)**. This may be due to the different CO₂ concentrations used in each study. The high yield under high calcium and CO₂ % conditions was likely related to reducing root and crown rot diseases which reflected the maximum recovery, positive impact on plant growth and increases nutritional use efficiency.

Table 6. Effect of calcium application during the growth of transplants and CO₂ % during transplant storage on early yield (ton / fed.) of strawberry Plants.

Calcium (kg/fed)	CO ₂ (%)					Mean
	2001/2002					
	0	10	20	30	40	
Control (0)	1.61 g	1.92 ef	1.70 fg	2.13 de	2.46 c	1.96 C
13	1.54 g	1.76 fg	2.44 c	2.01 e	3.44 b	2.24 B
26	2.04 e	2.36 cd	2.06 e	3.46 b	3.96 a	2.78 A
Mean	1.73 D	2.01 C	2.07 C	2.53 B	3.29 A	
2002 /2003						
Control (0)	2.23 ef	2.37 def	2.41 de	2.21 efg	2.70 bc	2.38 C
13	1.99 g	2.27 ef	2.37 def	2.97 a	2.65 bc	2.45 B
26	2.18 fg	2.39 def	2.54 cd	3.04 cd	2.83 ab	2.60 A
Mean	2.13 C	2.34 B	2.44 B	2.74 A	2.73 A	

Values followed by the same capital letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level. Small letters for interact

Table 7. Effect of calcium application during the growth of transplants and CO₂ % during transplant storage on total yield (ton / fed.) of strawberry Plants.

Calcium (kg/fed)	CO ₂ (%.) 2001/2002					Mean
	0	10	20	30	40	
Control (0)	14.98 de	14.22 ef	12.78 fg	18.58 c	20.23 bc	16.16 B
13	11.90 g	16.32 d	14.97 de	15.74 de	20.30 bc	15.85 B
26	12.71 fg	16.32 d	21.72 b	20.88 b	25.71 a	19.47 A
MEAN	13.20 D	15.62 C	16.49 C	18.40 B	22.08 A	
2002/2003						
Control (0)	16.14 h	16.54 gh	17.40 ef	21.91 b	25.02 a	19.40 B
13	16.53 gh	17.18 fg	17.72 ef	18.46 d	21.02 bc	18.18 C
26	17.83 df	17.91 de	18.46 d	20.74 C	24.79 a	19.95 A
MEAN	16.83 D	17.21 D	17.86 C	20.37 B	23.61 A	

Values followed by the same capital letter(s) do not significantly differ from each other according to Duncan's multiple range tests at 5% level. Small letters for interaction

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**تقليل تلف الشتلات عن طريق إضافة الكالسيوم والجو الهوائي المعدل أدى إلى
 زيادة محصول الفراولة**

[32]

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الشتلات بعد التخزين ونسبة وشدة الإصابة بالفطريات في الجذور والنتيجان وكذلك عدد الفطريات بزيادة معدلات التسميد بالكالسيوم وتركيزات غاز ثاني أكسيد الكربون حول الشتلات أثناء التخزين المبرد.

3- هناك زيادة معنوية في المحصول المبكر للشتلات بزيادة معدلات الكالسيوم وأعطى التسميد بالمعدل العالي من الكالسيوم زيادة معنوية في المحصول الكلي ولم يوجد فرق معنوي بين كل من معاملي صفر، 13 وحدة كالسيوم للفدان .

تجمل الدراسة انه يمكن تقليل نسبة تلف شتلات الفراولة أثناء التخزين المبرد وكذلك زيادة المحصول المبكر والكلي للشتلات بعد الزراعة وذلك بمعاملة الشتلات بمعدل 26 كجم من الكالسيوم للفدان وتخزين الشتلات في جو هوائي معدل (40% CO₂) .

أجريت هذه الدراسة خلال موسمي 2002/2001، 2003/2002 في مزرعة مركز تنمية الفراولة -كلية الزراعة -جامعة عين شمس بالنوبارية ومحطة بحوث البساتين بالقناطر بهدف دراسة تأثير التغذية بعنصر الكالسيوم لشتلات الفراولة في المشتل صفر 13، 26 كجم /الفدان) وتخزين الشتلات في جو هوائي معدل (صفر، 10، 20، 30، 40% ، CO₂) علي شدة ونسبة الإصابة بالفطريات وكذلك نسبة التلف للشتلات بعد فترة التخزين المبرد وعلاقة ذلك بالمحصول الكلي والمبكر للشتلات بعد الزراعة.

أوضحت النتائج ما يلي

1- ادت معاملات الكالسيوم إلى زيادة معنوية في نسبة الكالسيوم في النتيجان بينما نقص عدد الفطريات في كل من النتيجان والجذور بزيادة التسميد بالكالسيوم 0

2- يوجد نقص معنوي في كل من نسبة تلف