Agronomic behaviour and postharvest response to cold storage of Malvasio mandarin fruits

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Abstract — Introduction. The agronomic and post-harvest behaviour of Malvasio mandarin was studied in view of its introduction in commercial orchards as a late ripening mandarin. **Materials and methods**. Changes in quality parameters of Malvasio mandarin fruits from the beginning of January to the beginning of June, at month intervals, over a period of 3 years, were assessed. Also the potential storage life of the fruit harvested late in the season was studied. For that, fruit were stored after harvest for 3 months at 4 °C or 8 °C and 90% RH (relative humidity), then transferred, after each month of storage, during one week in simulated marketing conditions at 20 °C and 70–75% RH. Fruit were analysed, and appearance, chilling injury and decay were visually assessed. **Results**. The physical and chemical characteristics underwent few changes from January to June, and, until the beginning of June, the internal quality was always good. Fruit were very resistant to chilling injury, and not affected by the typical physiological disorders common to most of mandarins. However, the weight losses altered the esthetical aspect as usually happen for other cultivars of mandarins. The few chemical parameters changes did not reduce the internal quality of the fruit over the storage period. **Discussion and conclusion**. Malvasio mandarin has good agronomic aspects, good quality parameters, and an excellent behaviour in cold storage which make it available for a period of 8 months on the market, just when the production of mandarin in Italy is very poor. (© Elsevier, Paris)

Italy / *Citrus reticulata* / fruits / temperature resistance / cold storage / keeping quality

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Caractères agronomiques et comportement après-récolte de la mandarine Malvasio stockée au froid.

Résumé — Introduction. Le comportement au champ et en entrepôt de la mandarine Malvasio a été étudié afin de l'introduire en tant que mandarine tardive en vergers commerciaux. **Matériel et méthodes**. L'évolution de la qualité du fruit a été suivie, chaque mois, pendant 3 ans, de début janvier à début juin. Par ailleurs, la durée de vie potentielle de la mandarine stockée, récoltée en fin de saison, a été étudiée. Pour cela, des fruits ont été placés pendant 3 mois après leur récolte à 4 °C ou à 8 °C et à 90 % d'humidité relative (HR) ; après chacun de ces mois de stockage, ils ont été transférés, pendant une semaine, à 20 °C et 70–75 % HR, conditions simulant celles de sa commercialisation. Les fruits ont alors été analysés et leur apparence, les dégâts dus au froid et leur état sanitaire ont été observés. **Résultats**. De janvier à juin, les caractéristiques physiques et chimiques ont subi peu de changements et, jusqu'à début juin, la qualité interne est restée satisfaisante. Les fruits n'ont pas été endommagés par le froid et n'ont pas montré les désordres physiologiques typiques de la plupart des mandarines. Cependant, les pertes de poids ont altéré l'aspect des fruits comme il arrive souvent aux autres cultivars de mandarines. Les quelques changements des caractéristiques chimiques n'ont pas diminué la qualité interne du fruit pendant la période de stockage. **Discussion et conclusion**. La mandarine Malvasio a de bonnes caractéristiques agronomiques, une qualité satisfaisante et un excellent comportement en conditions de stockage au froid. Cela permet de la proposer sur le marché pendant 8 mois, alors que la production de mandarine en Italie est déficiente. (© Elsevier, Paris)

Italie / *Citrus reticulata* / fruits / résistance à la température / stockage au froid / aptitude à la conservation

1. introduction

Clementines and the whole range of "easy-to.peel" citrus fruits in the last 3 decades have conquered a strong market share. Especially amongst the young people, mandarins are being to be preferred to orange, which has an oldish image and suffer from the customs of the new society, which substituting snacks and fast meal to the traditional lunch or supper, find much easier to eat mandarins than oranges. As a consequence different countries have been introducing new clones and species of citrus ripening from September to April [1, 2], in order to make available citrus fruit also in summer months by means of cold storage. Unfortunately, in Italy, although since the early 80s scientific institutions have been proposing the introduction of new cultivars to lenghten the market period [3, 4], only some early and mid-season ripening cultivar have matched the favour of the industry [5]. So, there is a need of information related to behaviour of late ripening mandarins in order to promote their introduction in commercial orchards.

Malvasio mandarin, native from Argentina, has a good juice content and pleasant sub-acid flavour, and, amongst the mandarins, this cultivar is the one which more resembles the well accepted "mediterranean mandarin" (*Citrus deliciosa* Tan.). In Sardinia, it reaches an acceptable [total soluble solid/acid] ratio since the end of January, but can be hold on the tree until June, without substantial loss of quality. In spite of the excellent quality of the fruits, so far, Malvasio mandarin has received little attention from the citrus industry, either in Italy or in the rest of the world. Aiming to evaluate the feasibility of introducing in Sardinia this excellent cultivar of citrus, we followed the evolution of the quality of Malvasio mandarin fruit from January to June during a 3-year experiment, and we studied its potential storage life at the end of the third year of observation.

2. materials and methods

2.1. plant material

The fruit were harvest from twelve 15-year old trees of Malvasio mandarin at the Oristano experimental station of the National Research Council (CNR) of Italy , central Sardinia. The trees were grafted on sour orange and spaced 7 × 3.5 m. The trial consisted of two experiments. The first one was aimed to evaluate the changes in quality parameters of the fruit from the beginning of January to the beginning of June, at month intervals, over a period of 3 years. The second one had as objective the evaluation of the potential storage life of the fruit harvested late in the season, but still fresh and healthy. For this reason, the second experiment was carried out the third year, after having collected enough information on the evolution of the qualitative characteristics of the fruit over the previous three harvesting seasons.

2.1.1. experiment for evaluating changes in quality

At each inspection time a sample of 480 fruits free from any visual defect was collected from 12 different trees. In particular, 40 fruits of each single plant were harvested: 10 from every cardinal point at 1–1.5 m from the ground. All the fruits were combined, individually weighed, and, of each one, were measured the height, the width (average of two readings) and the rind thickness (average of four readings) using a calliper. The fruits were also checked for the number of seeds, then they were juiced using a hand reamer and the juice was centrifuged. Total soluble solids (TSS) and pH were measured with a hand refractometer and a pH-meter, respectively. Ten mL of juice were titrated against 0.1 N NaOH to end point (8.2) and titratable acidity calculated as % of citric acid. Vitamin C content of the juice was determined by the indolphenol titration method, as described by Ting and Rouseff [6]. Morphological parameters underwent non significant changes from January to June of the same year, therefore the data of each year were pooled together and analysed assuming as variable the three growing seasons. Otherwise, for chemical parameters an one-way analysis of variance was carried out for each inspection time of the single years. Means separation was accomplished by the LSD test.

2.1.2. experiment for evaluating the potential storage life

Fruits were harvested the 15th of May and only those presenting no visible alteration were selected. Prior to storage, half of them were dipped in a solution containing 250 mg·L^{-1} of imazalil. Fruits were then transferred to 4 °C or 8 °C and 95% relative humidity (RH). The storage period lasted 3 months, and, at month intervals, two lots of fruit from each treatment were removed from storage. One of the two lots was immediately used for qualitative and physiological examinations, while the remaining one was placed at 20 °C and 75% RH for an additional week in shelf-life (sl) to simulate retail conditions. At each inspection, time fruit were checked for decay, symptoms of chilling injury, quality overall appearance, weight loss, firmness, chemical analysis of the juice, and a panel test of ten untrained people carried out sensory evaluation. In addition, respiration rate and ethylene production were also measured. The same inspections were also carried out on the lot of fruit maintained in retail conditions for 1 week.

Ten fruit from each treatment were selected at random to determine respiration activity, as carbon dioxide, and ethylene evolution rate. The fruits were individually closed in 1-L glass jars for 2 h, then, from the same jars, they were withdrawn a 2 mL sample and a 20 mL one for, respectively, ethylene and carbon dioxide analysis. Before sampling the atmosphere inside the jars was agitated ten times with a 60-mL syringe. Ethylene was determined by a 3 300 Varian gas-chromatograph equipped either with a flame ionisation detector (FID) or a 1.82 m × 3.18 mm packed column (Unibeads®S, Alltech). Test conditions were: nitrogen as carries gas at a flow rate of 40 mL·min^{-1}; 150 °C, 100 °C and 200 °C were, respectively, the temperature of the injector, the oven and the detector. Carbon dioxide was measured injecting the 20-mL samples in an infrared gas analyser (Servomex, mod. 1450B3).

Chemical analyses were accomplished as for experiment for evaluating changes in quality.

Overall appearance was evaluated according to a scale ranging from 1 to 5, where 5 was the fruit as fresh as at harvest, free from any defect and ageing; 3 represented the limit of marketability; and 1 the fruit very aged.

Chilling injury was determined on the basis of visual signs of darkening of the peel, in the form of scald, and was scored according to a scale ranging from 0 to 4, with 0, nil, indicating no sign of chilling injury; 1, slight; 2, medium; 3, severe; and 4, very severe.

The sensory evaluation was carried out considering the two different storage temperatures. We did not consider the effect of the fungicidal treatment with imazalil on sensory attributes, in order to avoid of confusing the panellists with too many thesis, since, in previous trials carried out in our laboratory with other citrus fruits, no difference in taste was relieved in relation to chemical treatments.

Fruits were scored for overall acceptability according to a scale ranging from 5 to 1, were 5 indicated the highest degree of preference; 3 the limit of edibility; and 1 a very poor taste. Weight losses were determined on a sample of 40 fruits, while 10 fruits were used to measure firmness, expressed as mm of deformation of the equatorial diameter after having put under a weight of 1 kg for a period of 5 s each single fruit. Since either for weight loss or deformation, no significant differences were produced by the fungicidal treatment, data presented are only related to the storage temperatures.

The data were subjected to analysis of variance and the separation of the means was carried out by the LSD test.

3. results

3.1. assessing changes in quality

Data related to morphological parameters and juice content were fairly constant over the 3 years of observations. However some significant differences were relieved for the weight, which ranged from 98.6 g to 105.3 g, the rind thickness, the number of

Table I.
Annual changes of some external and internal physical characteristics of Malvasio mandarin fruits at the harvest.

Year	Height (mm)	Width (mm)	Height/width	Weight (g)	Rind thickness (mm)	Number of seeds	Juice content (%)
1994	4.95[a]	6.18[a]	0.80[a]	98.6[a]	2.8[ab]	3.2[a]	53[a]
1995	5.08[b]	6.21[a]	0.82[a]	102.6[ab]	3.1[b]	4.6[b]	51[a]
1996	5.02[ab]	6.29[b]	0.80[a]	105.2[b]	2.4[a]	3.4[a]	54[a]
Test significance	*	*	ns	*	*	*	ns

ns: not significant differences.
a, b: in a same column, groups signicatively different according to the least significant difference (LSD) test at $p = 0.05$.

Table II.
Chemical parameter changes of Malvasio mandarin fruit from January to June during the 1994, 1995, and 1996 seasons.

Date	pH	Titratable acidity (% citric acid)	Total soluble solid (°Brix)	Maturity index	Vitamin C ($mg \cdot 100\ mL^{-1}$)
1994					
January	3.18[a]	1.38[e]	12.1[c]	8.8[a]	40.5[bc]
February	3.20[a]	1.25[d]	11.9[c]	9.5[b]	41.2[c]
March	3.22[b]	1.15[c]	12.2[c]	10.6[c]	40.3[bc]
April	3.20[a]	1.12[c]	12.3[c]	11.0[cd]	42.0[d]
May	3.31[b]	0.98[b]	11.1[b]	11.3[d]	39.6[b]
June	3.41[c]	0.83[a]	10.3[a]	12.4[e]	30.3[a]
1995					
January	3.03[a]	1.83[c]	12.5[a]	6.7[a]	41.3[b]
February	3.15[b]	1.80[c]	12.9[ab]	7.2[ab]	42.4[c]
March	3.13[b]	1.69[b]	13.3[b]	7.9[b]	42.3[c]
April	3.18[bc]	1.70[b]	13.2[b]	7.7[b]	44.8[d]
May	3.21[c]	1.67[b]	13.5[b]	8.1[b]	42.3[c]
June	3.34[d]	1.11[a]	13.1[b]	11.8[c]	36.7[a]
1996					
January	3.08[a]	1.75[b]	11.2[a]	6.4[a]	42.1[a]
February	3.19[b]	1.72[b]	12.5[b]	7.3[b]	43.6[b]
March	3.18[b]	1.70[b]	12.6[b]	7.5[b]	43.5[b]
April	3.21[b]	1.73[b]	13.0[b]	7.5[b]	44.2[b]
May	3.20[b]	1.72[b]	13.8[c]	8.0[c]	46.5[c]
June	3.29[c]	1.59[a]	13.6[c]	10.4[d]	41.8[a]

a, b, c, d, e: in a same column anf for a same year, groups significatively different according the least significant difference (LSD) test at $p = 0.05$.

seeds as well as the juice content which was always higher than 50% (*table I*). These results agree with those previously reported by Agabbio and Casu [4] in Sardinia and Protopapadakis [7] in Crete. On the other hand, a remarkable variability was detected for chemical parameters of the juice during the 3 years (*table II*). In 1994, the titratable acidity was particularly low. In fact, in January, it was 1.38%, lower than it was in May

1995 (1.67 %) or in June 1996 (1.59%). Over all the sampling periods of 1994, even TSS and vitamin C reported the lowest values of the corresponding periods of 1995 and 1996. Regarding the evolution of chemical parameters, from January to June of each respective year, the biggest variations interested the titratable acidity. Vitamin C content in general was stable until June, while, with the exception of 1994, TSS increased by January until June, consequently, the maturity index had a progressive rise over the inspection times. The little variation of the chemical parameters from January to June, associated with the high juice content, which never dropped below 50%, make this mandarin very different from other cultivars, which, after reaching the ripe stage, usually have a short "on-tree" life with retention of satisfactory quality restricted to few weeks, and consequent "puffing" of the rind and rapid acidity and juice reduction [8].

3.2. assessing the potential storage life

Respiration rate which was about 13 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ at harvest, decreased to 4 and 6 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ after, respectively for fruit stored at 4 or 8 °C, and it remained on these levels for the whole storage period (*figure 1*). A burst in respiration activity was observed after 24 h following the removal from storage, after 1, 2 or 3 months, when the fruit were transferred to 20 °C in simulated marketing conditions. After the week of simulated marketing conditions, for each inspection time, carbon dioxide production rate decreased markedly. Either after 24 h following the removal from storage conditions or after 1 week at 20 °C, the respiration activity increased by the time in storage (1, 2 or 3 months). These results are in contrast with those reported by McCollum and McDonald [9] who detected a decrease in respiration rate during the first 3 months in storage of Marsh grapefruits, but they agree with the pattern observed by other researchers with oranges [10] and grapefruits [11]. With the exception of the first month, where, the day following the transfer to 20 °C, fruit stored at 4 °C produced more carbon dioxide than those stored at 8 °C, the respiration activity was similar both for fruit stored at 4 °C and for those stored at 8 °C. With other citrus fruits such as lemons and grapefruits [12, 13], a higher respiratory activity has been observed in fruit stored at lower temperatures following transfer to retail marketing conditions at 20 °C. Increase in respiration rate during the first 24 h following transfer to 20 °C followed by a significant reduction has been observed by several authors for several chilling sensitive species [14], and this response seems due to an uncoupling of oxidative phosphorylation [14], which is not necessarily associated to an irreversible symptom of chilling injury. In fact, Eaks [13] found that the internal CO_2 of lemon fruits stored for 8 or 12 weeks at 0 °C did not return to the level of the control even after 24 h at 20 °C and he suggested that a sustained increase in respiration activity following long periods of chilling exposure could be indicative of the irreversible metabolic disturbance and accumulation of the oxidizable intermediates. Thus, our results indicate that, even after 3 months of storage, there was no

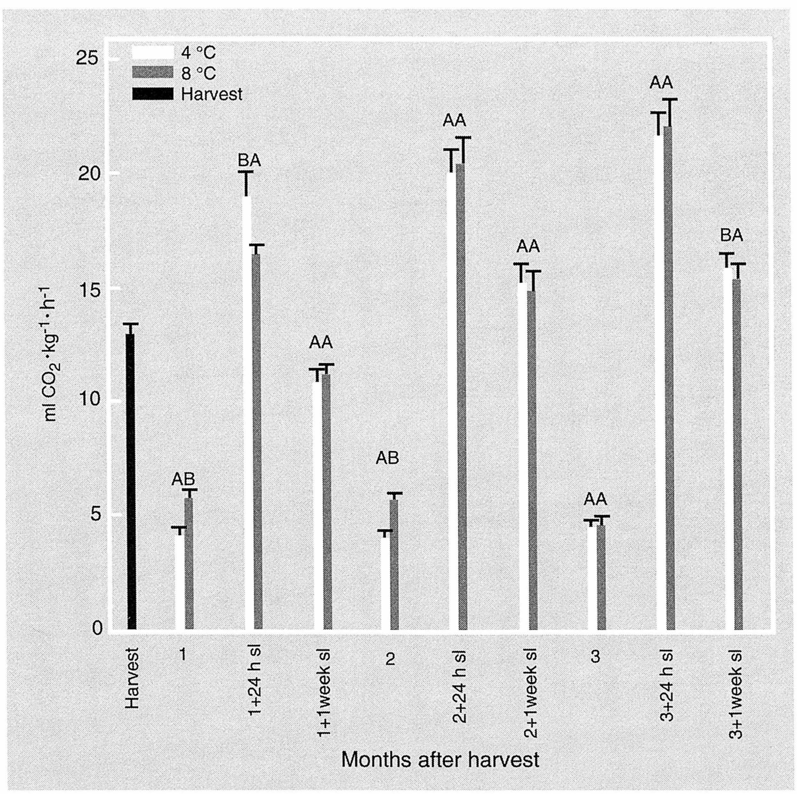
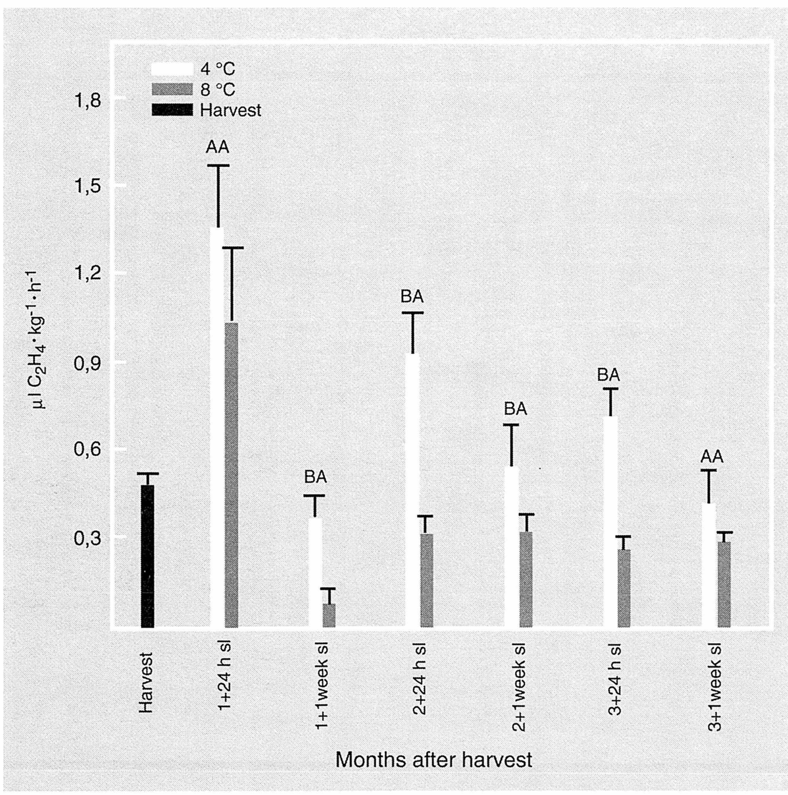


Figure 1.
Effect of storage temperatures on respiration rate of Malvasio mandarin fruits after 1, 2 or 3 months of storage, and the respective shelf-life (sl) periods at 20 °C following 24 h or 1 week the removal from storage at 4 °C or 8 °C . Means separation by the LSD test at the 5% level; vertical bars represent standard errors (n =10).

symptoms of chilling injury associated with the respiratory pattern and that fruit stored at 4 °C had the same response as the fruit stored at 8 °C. No significant influence had the treatment with imazalil on respiration rate (data not shown).

Ethylene production was 0.5 $\mu L \cdot kg^{-1} \cdot h^{-1}$ at harvest (*figure 2*). In storage conditions, it was never detected, with the exception of some occasionally incipient decay (data not shown). Otherwise, a burst of ethylene production was observed 24 h after the transferring to 20 °C. Thereafter, a consistent decrease occurred during the week at 20 °C in simulated marketing conditions. Total amount of ethylene production decreased by the time in storage. Fruit which were stored at 4 °C always produced more ethylene than those stored at 8 °C, and these differences, with the exception of the 24 h following the first month of storage, were always significantly different. Our data related to ethylene production agree with those reported by McCollum and McDonald [9] and Vines et al. [15] who were able to detect, in storage conditions, ethylene only in grapefruits which were previously chilly stressed. Chilling sensitive plant can respond differently to chilling temperatures; some tissues produce large amount of ethylene even during chilling exposure, while others are able to promote ethylene production only after being transferred to warmer temperatures [16]. Malvasio mandarin fruit seems to belong to the latter group. After the transfer to 20 °C, an overshot of ethylene production was detected, and this overshot was markedly more pronounced in fruit stored at 4 °C than in those at 8 °C. Chilling temperature, therefore, seemed to induce ethylene production only after that chilling exposure ceased, probably by a new synthesis of 1-aminocyclopropane-1-carboxylic acid (ACC) when fruit were placed at 20 °C. On the other hand, the burst in ethylene production was transient; in fact, the production underwent a remarkable reduction after the week in simulated shelf-life conditions. The stimulatory effect of low temperature might not be regarded as a symptom of chilling injury, but simply as a "normal" physiological effect of the low temperature; in some cases, if the severity and the length of exposure to chilling temperature are higher than specific thresholds, the ethylene forming enzyme (EFE) system can be damaged and, as a consequence, following the transfer to warmer temperatures, no increase in ethylene production may occur [16]. As observed for respiration rate, no significant influence had the treatment with imazalil on ethylene evolution.

Figure 2.
Effect of storage temperatures on ethylene production rate of Malvasio mandarin fruits after 1, 2 or 3 months of storage, and the respective shelf-life (sl) periods at 20 °C following 24 h or 1 week the removal from storage at 4 °C or 8 °C.
Means separation by the LSD test at the 5% level; vertical bars represent standard errors (n = 10).



The effect of imazalil on weight losses (data not shown) was not influent; very important was, otherwise, the effect of the storage temperature. Weight losses of fruit held at 4 °C after 3 months of storage (8%) were less than those of fruit stored at 8 °C after 1 month (9%) (*figure 3*). The rate of transpiration decreased with the time in storage; in fact, while after 1 month at 4 °C and 8 °C the weigth losses were of about 4% and 9% respectively, from the second to the third month the increases were of 1% and 3%. However, as reported for other refrigerated cultivars of mandarin-like fruits [17,18], transpiration rate was very high, reaching almost 19% in fruit stored for 3 months at 8 °C plus 1 week at 20 °C.

Firmness, measured as mm of deformation (*figure 4*), had a trend very similar to that of weight loss. In fruit stored at 4 °C, the increase in deformation was rather linear in storage conditions. In those held at 8 °C, there was a sharp increase during the first months of storage, then they changed approximately with the same rate of the fruit stored at 4 °C until the third month of storage, with an average difference of about 1 mm. The deformation increased sharply during the simulated retail conditions which followed the respective inspection time after 1, 2 or 3 months of storage.

Malvasio mandarin fruits showed a very high resistance to low temperatures. Chilling injury appeared as a soft brown scald on the peel. In fruit stored at 4 °C, the incidence of these alterations was higher than those stored at 8 °C, and a positive effect was induced by imazalil, but either the beneficial effect of the higher temperature or that due to the treatment with imazalil were not consistent over the storage period (*table III*). In fact, chilling injury affected only sporadically some fruits and, basically, had no negative influence on their esthetical aspect.

Overall appearance changed dramatically over the 3 months of storage, especially after the simulated retail conditions (*table III*). The changes were caused mainly by the excessive weight losses, which led the peel to shrink and get flaccid. As consequence, the peel lost brightness and aged rapidly. Although the contribution of imazalil in reducing transpiration rate was not significant, a positive effect was observed in delaying ageing of the peel. Very important was the influence of the temperature on esthetical aspect of the fruit; in particular, fruit

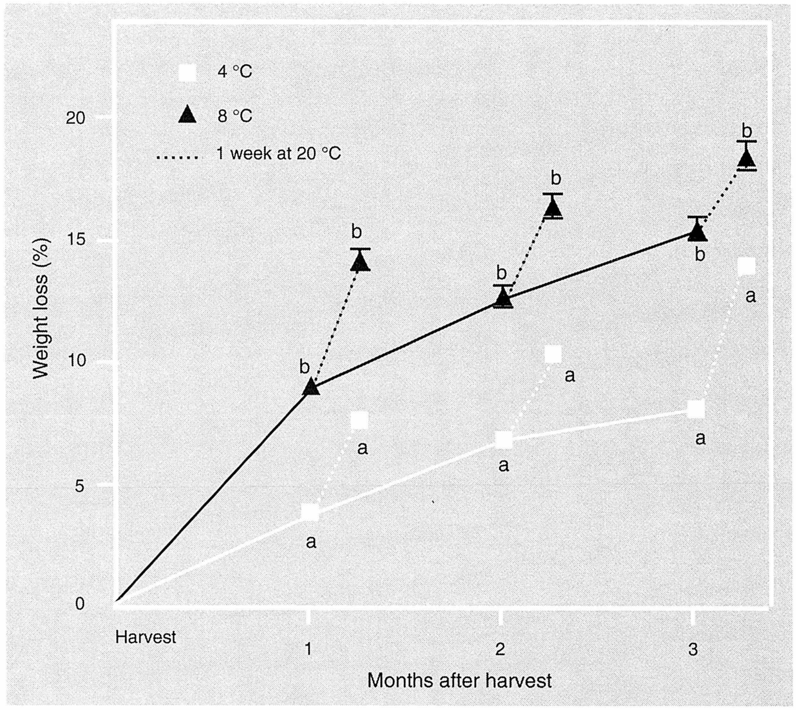


Figure 3.
Effect of storage temperatures on weight loss of Malvasio mandarin fruits after 1, 2, or 3 months of storage and the respective 1-week periods of simulated shelf-life conditions at 20 °C. Means separation by the LSD test at the 5% level; vertical bars represent standard errors (no fruits = 50) .

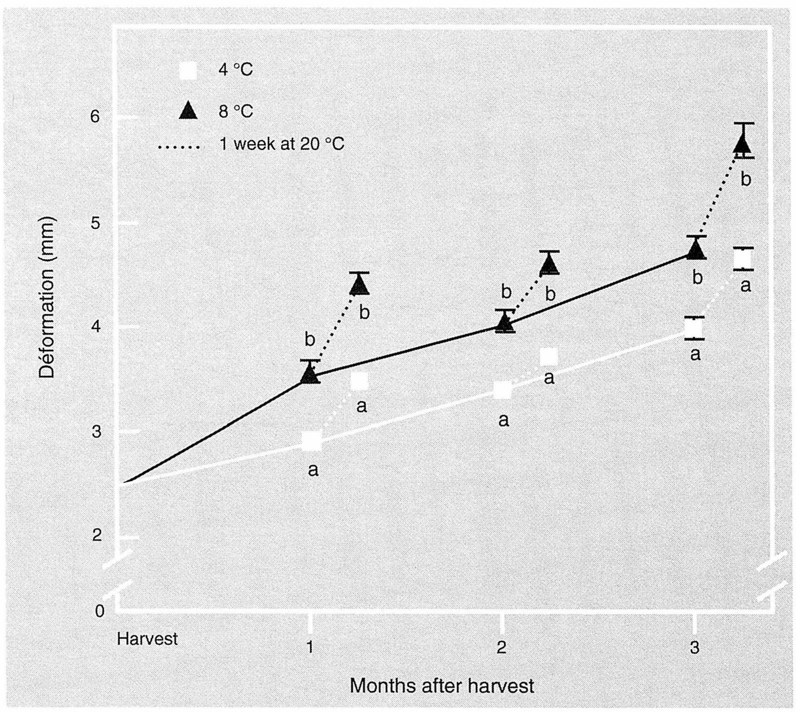


Figure 4.
Effect of storage temperatures on firmness of Malvasio mandarin fruits after 1, 2, or 3 months of storage and the respective 1-week periods of simulated shelf-life conditions at 20 °C. Means separation by the LSD test at the 5% level; vertical bars represent standard errors (no fruits = 10).

Table III.
Effect of treatments with imazalil (IMZ) on overall appearance, chilling injury and incidence of decay in Malvasio mandarins stored for different periods at 4 °C or 8 °C and 90% relative humidity (RH), followed by an additional week of simulated marketing conditions at 20 °C and 75% RH.

Storage period length	Overall appearance[1]		Chilling injury[2]		Decay (%)		Overall preference[3]	
	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C
Harvest	5	—	—	—	—	—	4.85	—
1 month								
4 °C without IMZ	4.9^{c}	3.6^{a}	0.32	0.73^{b}	6^{b}	9^{b}	4.85^{a}	4.75^{a}
with IMZ	4.9^{c}	4.4^{b}	0.27	0.61^{ab}	0^{a}	1^{a}	—	—
8 °C without IMZ	3.5^{a}	2.6^{a}	0.30	0.53^{ab}	5^{b}	5^{b}	4.70^{a}	4.70^{a}
with IMZ	4.1^{b}	2.9^{b}	0.26	0.39^{a}	0^{a}	1^{a}	—	—
Test significance								
Fungicide (F)	***	**	ns	ns	**	*	—	—
Temperature (T)	***	**	ns	*	ns	ns	ns	ns
FxT	***	ns	ns	ns	ns	ns	—	—
2 months								
4 °C without IMZ	2.9^{a}	3.2^{b}	0.86^{b}	0.57^{c}	11^{c}	17^{b}	4.8^{a}	4.5^{b}
with IMZ	3.8^{b}	3.4^{b}	0.40^{a}	0.43^{ab}	2^{a}	2^{a}	—	—
8 °C without IMZ	2.4^{a}	1.7^{a}	0.32^{a}	0.36^{a}	15^{c}	5^{a}	4.6^{a}	3.6^{a}
with IMZ	3.7^{b}	1.9^{a}	0.35^{a}	0.47^{b}	5^{b}	1^{a}	—	—
Test significance								
Fungicide (F)	**	*	***	*	*	***	—	—
Temperature (T)	***	***	***	*	ns	**	ns	*
FxT	*	ns	***	ns	ns	**	—	—
3 months								
4 °C without IMZ	3.5^{b}	1.9^{bc}	0.69	0.92	12^{b}	22^{b}	4.1^{b}	3.5^{b}
with IMZ	3.9^{c}	2.2^{c}	0.64	0.93	3^{a}	3^{a}	—	—
8 °C without IMZ	2.4^{a}	1.4^{a}	0.62	0.93	14^{b}	23^{b}	3.3^{a}	2.7^{a}
with IMZ	2.6^{a}	1.8^{b}	0.65	0.94	1^{a}	4^{a}	—	—
Test significance								
Fungicide (F)	**	***	ns	ns	*	*	—	—
Temperature (T)	***	***	ns	ns	ns	ns	*	*
FxT	ns	ns	ns	ns	ns	ns	—	—

a, b, c : in a same column and for a same period of storage, groups significatively different according to the least significant difference (LSD) test at $p = 0.05$.
[1] Overall appearance evaluated according to a scale ranging from 1 to 5: 5, fruit as fresh as at harvest; 3, limit of marketability; 1 = fruit very aged.
[2] Chilling injury symptoms scored according to a scale ranging from 0 to 4: 0, nil; 1, slight; 2, medium; 3, severe; 4, very severe.
[3] Overall preference, as sensory evaluation, rated on a scale ranging from 5 to 1: 5, the highest degree of acceptability; 3, the limit of edibility; 1, a very poor taste.

stored at 4 °C reported a score higher than 3, which was assumed as the limit of marketability, until after the 1 week of simulated retail conditions at 20 °C following 2 months of storage; most of them were still marketable after 3 months at 4 °C, while fruit stored at 8 °C had a score less than 3 since after 2 months. The score was related only to the exterior aspect of the fruit. Regarding the internal aspect, both the fruit stored at 4 °C and 8 °C appeared acceptable over the whole trial, and no signs of granulation or desiccation of the pulp appeared (data not shown), although these symptoms are very common for mandarins.

Incidence of decay increased by the time in storage, and no important difference was observed between fruit stored at 4 °C or 8 °C (*table III*). Until the second inspection time, green mould (*Penicillium digitatum*) accounted for almost all the decayed fruit, while, after the third month of storage and the respective week of simulated marketing conditions at 20 °C, decay caused by *Penicillium digitatum* was about 80% and the remaining 20% was due to alternaria and antrachnose. Imazalil was very effective in reducing decay caused by penicillium, and, consequently, most of the rotten fruits observed in imazalil treated thesis were caused by alternaria and, in less amount, by anthrancnose.

Internal quality attributes changed only in relation to the storage period, while little influence had both the treatment with imazalil and the different storage temperatures (*table IV*). Juice content which was 52% at harvest did not change in storage and was always higher than 50%. The value of pH increased from 3.2 at harvest to almost 4 after 1 week of simulated marketing conditions following 3 months of storage, with intermediate values along the storage periods. Titratable acidity decreased progressively from 1.72% of citric acid at harvest to less than 1% at the end of the trial. From harvest to the end of trial a loss of vitamin C of about 24% was registered.

In general, neither the different temperature nor the treatment with imazalil had important and consistent effect on internal quality attributes of the fruit. Until after 2 months of storage, the panellists did not find difference between fruit stored at 4 °C or 8 °C, and the score basically did not change from harvest (*table IV*). It was only from after the first week of simulated marketing conditions at 20 °C following 2 months of refrigeration that the fruit stored at 4 °C were rated better than those stored at 8 °C. In any case, they were judged acceptable even at the end of the trial, even if those stored at 4 °C had a higher score.

4. discussion and conclusion

Few data are available on the literature related to Malvasio mandarin. Hodgson [8] reported that it holds well on the tree and that has good postharvest characteristics. The parameters we took in consideration related to morphological aspect underwent slight changes from the beginning of January to the beginning of June. The internal quality aspects were also very stable. Sugars content remained higher than 50% for all the period, while in other kinds of mandarins cultivated in Italy, as clementines and Mediterranean mandarins, they usually reach the best quality attributes after a few weeks, then flesh loses rapidly juice and dries. Although a very high variation occurred among the 3 years, the acidity was high enough even in June as also the vitamin C content. The results indicate therefore that Malvasio mandarin can be stored well on the tree for 6 months without any loss of quality attributes.

Malvasio mandarins showed to be very suitable for long term storage. The fruit can withstand storage for long periods at low temperatures, without appreciable signs of chilling injury. In addition, the fruit are very resistant to some physiological alterations very common to mandarins such as granulation, desiccation and loss of juiciness, and present very high grade of internal quality parameters. On the other hand regarding weight loss and ageing, Malvasio mandarins are similar to the other tangerins and easy peeling citrus fruit. In any case, this problem can be solved by the use of coatings and film wrapping.

Table IV.
Effect of treatments with imazalil (IMZ) on internal quality of Malvasio mandarins stored for different periods at 4 °C or 8 °C and 90% relative humidity (RH), followed by an additional week of simulated marketing conditions at 20 °C and 75% RH.

Storage period length	Juice content (%)		pH		Titratable acidity (% citric acid)		Total soluble solid (°Brix)		Maturity index		Vitamine C (mg·100 mL^{-1})	
	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C	At transfer to 20 °C	After 1 week at 20 °C
Harvest	52	—	—	—	—	—	4.85	—				
1 month												
4 °C without IMZ	52	54	3.38	3.45	1.31	1.21	13.9	13.5^{ab}	10.6	11.2	43.1	36.3^{a}
with IMZ	52	53	3.46	3.48	1.28	1.23	14.0	13.0^{a}	10.9	10.6	42.0	38.2^{ab}
8 °C without IMZ	53	53	3.30	3.48	1.23	1.22	14.0	13.5^{ab}	11.4	11.1	43.3	37.0^{ab}
with IMZ	53	53	3.41	3.46	1.25	1.22	13.5	13.9^{b}	10.8	11.4	41.1	39.7^{b}
Test significance												
Fungicide (F)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*
Temperature (T)	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
FxT	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
2 months												
4 °C without IMZ	51	52	3.46^{a}	3.55^{a}	1.15	1.03	13.3^{a}	13.7	11.6^{a}	13.3^{a}	37.0^{a}	36.0
with IMZ	52	53	3.48^{a}	3.61^{b}	1.05	1.00	14.0^{b}	13.6	13.3^{b}	13.6^{a}	38.7^{ab}	36.2
8 °C without IMZ	53	52	3.52^{b}	3.66^{bc}	1.08	1.02	14.5^{b}	14.4	14.4^{c}	14.1^{b}	43.0^{b}	36.0
with IMZ	53	51	3.50^{b}	3.71^{c}	1.07	0.98	13.9^{b}	14.1	13.0^{b}	14.4^{b}	41.0^{ab}	36.5
Test significance												
Fungicide (F)	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
Temperature (T)	ns	ns	*s	**	ns	ns	*	ns	*	*	**	ns
FxT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
3 months												
4 °C without IMZ	50	52	3.68^{a}	3.68^{a}	1.09^{b}	0.95^{c}	13.8	13.6	12.7^{a}	14.3^{a}	40.1	36.3
with IMZ	51	50	3.72^{a}	3.82^{b}	1.06^{ab}	0.89^{b}	13.8	13.6	13.0^{a}	15.3^{ab}	39.5	35.6
8 °C without IMZ	51	53	3.93^{b}	3.93^{c}	0.94^{a}	0.88^{b}	14.0	14.1	14.9^{b}	16.0^{bc}	41.0	36.0
with IMZ	50	50	3.98^{b}	3.96^{c}	0.88^{a}	0.83^{a}	13.9	13.8	15.8^{b}	16.6^{c}	39.7	33.4
Test significance												
Fungicide (F)	ns	ns	ns	**	ns	*	ns	ns	ns	ns	ns	ns
Temperature (T)	ns	ns	**	***	*	*	ns	ns	*	*	ns	ns
FxT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

a, b, c: in a same column and for a same period of storage, groups significatively different according to the least significant difference (LSD) test at $p = 0.05$.

In conlusion, we believe that Malvasio mandarin is a valid cultivar which is worth while to be introduced in commercial orchard either for the good agronomic aspects or for the good quality parameters, which, associated with the excellent behaviour in cold storage, make available this speciality citrus fruit for a period of 8 months on the market (from January to September), just when the production of mandarin in Italy is very poor.

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Caracteres agronómicos y comportamiento pos cosecha de la mandarina Malvasio almacenada en frío.

Resumen — Introducción. Se estudió el comportamiento en campo y en almacén de la mandarina Malvasio con tal de introducirla como mandarina tardía en vergeles comerciales. **Material y métodos**. Se siguió vigilando la evolución de la calidad de la fruta, cada mes, durante 3 años, desde principios de enero hasta principios de junio. Por otro lado, se estudio la duración de vida potencial de la mandarina almacenada, cosechada al terminarse la temporada. Para esto, se colocaron frutas durante 3 meses después de cosecharlas a 4 °C o a 8 °C y a 90% de humedad relativa (HR); después de cada uno de estos meses de almacenamiento, fueron transferidas, durante una semana, a 20 °C y 70–75 % HR, condiciones simulando las de su comercialización. Se analizaron entonces las frutas y su apariencia, se observaron los daños provocados por el frío y su estado sanitario. **Resultados**. Desde enero hasta junio, las características físicas y químicas sufrieron pocos cambios y, hasta principios de junio, la calidad interna se quedo satisfactoria. Las frutas no fueron deterioradas por el frío y no mostraron desordenes fisiológicos típicos de la mayoría de las mandarinas. No obstante, las pérdidas de peso alteraron el aspecto de las frutas como ocurre a menudo en los demás cultivares de mandarinas. Los pocos cambios de las características químicas no disminuyeron la calidad interna de la fruta durante el periodo de almacenamiento. **Discusión y conclusión**. La mandarina Malvasio tiene buenas características agronómicas, una calidad satisfactoria y un excelente comportamiento en condición de almacenamiento en frío. Esto permite proponerla en el mercado durante 8 meses, mientras que la producción de mandarina en Italia es deficiente. (© Elsevier, Paris)

Italia / *Citrus reticulata* / frutas / resistencia a la temperatura / almacenamiento en frío / aptitud para la conservación