explaining low or partial correlations, especially between developmentally unrelated characters. Because more genes may be involved in ft wt inheritance (6) than in quality traits (5, 9) the possibility for various degrees of linkage cannot be ignored. However, it was observed that the genetic variance of pH was the lowest (Table 2), thus genetic sampling for this trait may have been a source of error (2) contributing to a downward bias of correlation estimates for pH-Brix and pH-ft wt comparisons.

The data on the relationships of fruit weight to quality traits suggest that genetic improvement in this trait would be accompanied by little, if any, genetic improvement in fruit soluble solids and acidity. However, where fruit size can be subordinated somewhat to fruit quality considerations, as in the development of processing cultivars, breeding to combine high soluble solids and high acidity should be a relatively easy objective to achieve.

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Influence of Atmospheric Moisture, Ion Balance, and Ion Concentration on Growth, Transpiration and Blackheart of Celery (*Apium graveolens* L.)[1]

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Abstract. Intermittent misting of celery plants grown in nutrient solutions resulted in higher top and sucker fresh weights and a lower percentage of dry matter. Misting reduced transpiration up to 27% but did not affect ion uptake nor the incidence of blackheart.

Total top and sucker fresh weights generally decreased with increasing Ca/K ratio in the nutrient solutions while percentage dry matter increased. The 50ppm Ca/235 ppm K ratio resulted in a high water-use efficiency while the 200/59 ratio resulted in a low efficiency. Blackheart symptoms decreased with increasing Ca/K ratio.

Osmotic concentrations of 0.3 and 4.8 atm. in the nutrient solutions decreased both the fresh and dry weights of tops but increased the percent dry matter as compared to the 1.2 atm. nutrient solution. Water-use efficiency was lower at the 0.3 than at the 1.2 and 4.8 atm. concentrations. Blackheart was most severe in the 1.2 atm. solutions.

Plant water balance is critical to many plant processes. Numerous methods may be used to prevent or reduce the development of water stress in plants. These include misting by overhead irrigation (4), manipulation of the soil moisture level (5), the ion concentration (6, 11), or the ion balance (2).

Blackheart of celery, a physiological disorder characterized by the deterioration of heart tissue, has been closely associated with unbalanced water relations and heavy fertilizer applications (1, 3, 12, 14). A low Ca content in the celery heart tissue is characteristic of plants with blackheart symptoms (1, 8, 12). In the case of celery, Ca may affect water balance in the plant (2) or conversely - water balance may affect Ca uptake and metabolism (7).

The purpose of this study was to investigate the effects of ion concentration, ion balance, and atmospheric treatments on growth, water balance and the incidence of blackheart in celery.

Materials and Methods

Experiment 1. Celery plants, cv. Utah 52-70, were established in aerated half-strength Hoaglands No. 2 nutrient solution (9) in 2-gallon crocks on greenhouse benches. On May 13, 1966 the following treatments were imposed in a split-plot design with 4 replications: main plots - 1) mist, 2) control, 3) heat lamps; sub-plots) - a) 50 ppm Ca/235 ppm K, b) 100 ppm Ca/176 ppm K, c) 150 ppm Ca/117 ppm K, d) 200 ppm Ca/59 ppm K.

Treatments of the main plots were applied every day between 9:00 a.m. and 4:00 p.m. Deionized water mist was applied from fine nozzles for 2 seconds every 3 or 6 minutes depending on the atmospheric conditions. This insured that the leaves were moist but not dripping. Normal greenhouse conditions (21°C night temperature) constituted the control. In treatment 3, 250 watt infrared heat lamps were placed 14 inches above the foliage with one lamp supplying heat radiation to 2 plants.

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The sub-plot treatments consisted of Hoaglands No. 1 solution (9) with Ca and K contents modified by altering the $Ca(NO_3)_2$ and KNO_3 added. Amonium nitrate was added as needed to correct the N levels. The pH of the solutions was adjusted to 6.0 by adding KOH or $Ca(OH)_2$ and reducing accordingly the small amount of KNO_3 or $Ca(NO_3)_2$ that had been withheld to make the K or Ca correction. Solutions were changed weekly.

Periodically the plants were lifted and weighed and ratings of severity of blackheart symptoms recorded. Water utilization from solutions was recorded daily.

Final records of plant characteristics were made on June 17, 1966. Chemical analyses were run on the heart tissue consisting of leaves under 8 inches in length cut just above the stem plate. Potassium content was determined with a flame photometer, and Ca with a direct reading photoelectric spectrometer. Analysis of variance was performed on the data and mean comparisons were made using Duncan's Multiple Range Test. Simple linear correlations of blackheart ratings with other recorded data were run.

Experiment 2. Celery transplants were placed in nutrient solutions on June 25, 1966 and the following treatments imposed on July 29, 1966 in a split-split-plot design with 2 replications: main plots - 1) 100 ppm Ca/176 ppm K, 2) 200 ppm Ca/59 ppm K; sub-plots - A) mist, B) control; sub-sub-plots -a) 0.3 atm. concentration, b) 1.2 atm. concentration, c) 4.8 atm. concentration.

Main plot and sub-plot treatments were carried out as described in Experiment 1.

In the sub-sub-plots the osmotic concentrations were adjusted to 0.3, 1.2 and 4.8 atm. by altering the amount of each element in the solutions while maintaining the same ratio between the elements. The pH of the solutions was adjusted to 6.0 as in Experiment 1.

Records were taken and analysed as indicated in Experiment 1. In addition, temperatures of air, plant and solution were recorded using copper-constant thermocouples. Observations were completed on September 24, 1966.

Results

Experiment 1. Misting increased the weight of suckers per plant and decreased the percentage of dry matter in the tops compared to the control and heat lamp treatments (Table 1). The environmental treatments had no effect on the Ca/K ratio in heart tissue, nor on blackheart ratings. Mist decreased transpiration, however, while heat lamps increased it.

The two highest Ca/K ratios decreased top and sucker weights (Table 1). The percent dry matter increased, therefore there was no significant difference in top dry matter among the treatments. With increasing Ca/K ratio in the nutrient solution there was an increase in Ca/K ratio in the heart tissue, a decrease in the severity of blackheart symptoms and an increase in volume of water transpired per g of dry matter produced.

Blackheart severity increased with increasing top fresh weight, sucker weight and K content in the heart, while symptoms decreased in severity with increasing top percentage dry matter, Ca content in hearts and Ca/K ratio in hearts (Table 3).

Experiment 2. The 200/59 Ca/K ratio nutrient solution resulted in a significantly lower total top weight than the 100/176 ratio solution (Table 2). The interaction of Ca/K ratio X solution concentration on marketable weight was significant, indicating that the marketable weight was higher in 200/59 ratio solutions than in 100/176 ratio solutions at 1.2 and 4.8 atm. concentrations, but lower at 0.3 atm.

Misting produced a significant increase in the total top fresh weight above that of the control (Table 2). It also reduced the volume of water transpired per g of dry matter produced from 433 ml for the control to 316 ml.

The 1.2 atm. solution yielded higher total top and sucker fresh weight, top dry weight and lower percent dry matter in the tops than either the 0.3 atm. or 4.8 atm. (Table 2). In these

Table 1. Growth of celery plants related to environment and nutrient solution Ca/K ratio.[x]

	Fresh wt. per plant (g)		Top dry matter (%)	Ca/K ratio in heart tissue	Black-heart ratings[y]	Water transpired per g dry matter (ml)
	Total top	Sucker				
Environment						
1 Mist	1277a	555a	9.5b	.036a	4.34a	287c
2 Control	1132a	406b	10.3a	.031a	4.28a	360b
3 Heat Lamps	1148a	434b	10.2a	.041a	4.09a	417a
Ca/K Ratio						
a 50/235	1285a	550a	9.3c	.018c	5.31a	326c
b 100/176	1311a	609a	9.4c	.036b	4.48ab	344b
c 150/117	1123b	395b	10.2b	.035b	4.17b	348b
d 200/59	1025c	307b	11.2a	.056a	3.00c	403a

[x] Values followed by uncommon letters are significantly different at the 5% level.
[y] 1 = no symptoms; 9 = severe symptoms.

Table 2. Growth of celery plants related to environment, nutrient solution Ca/K ratio and concentration.

	Fresh wt per plant (g)			Top dry wt per plant (g)	Top dry matter (%)	Ca/K ratio in heart tissue	Black-heart rating[y]	Water transpired per g dry matter (ml)
	Total top	Mkt. top	Sucker					
Ca/K ratio								
1 100/176	1036a	450a	309a	90.4a	8.7a	.062a	2.9a	365a
2 200/59	900b	476a	181a	85.0a	9.5a	.108a	1.6a	384a
Environment								
A Mist	1052a	501a	285a	91.6a	8.7a	.083a	2.0a	316b
B Control	885b	425a	205a	83.8a	9.5a	.087a	2.5a	433a
Solution conc.								
a 0.3 atm.	799b	438ab	137b	79.3b	9.9a	.115a	1.9ab	421a
b 1.2 atm.	1144a	515a	352a	98.3a	8.6b	.082b	2.6a	362b
c 4.8 atm.	713b	345b	134b	72.8b	10.2a	.078b	1.5b	347b

[x] Values followed by uncommon letters are significantly different at the 5% level.
[y] 1 = no symptoms; 9 = severe symptoms.

Table 3. Relationship of blackheart rating to celery plant characteristics (simple linear correlation coefficients).

	Blackheart rating	
	Experiment 1	Experiment 2
Top fresh wt	+.351*	+.337
Sucker wt	+.384**	+.518**
K content in heart	+.557**	+.534**
Top percent dry matter	-.416**	-.434*
Ca content in heart	-.693**	-.436*
Ca/K ratio in heart	-.719**	-.543**

*Significant at the 5% level.
**Significant at the 1% level.

measurements 0.3 atm. and 4.8 atm. solutions were not significantly different from each other. The 0.3 atm. concentration resulted in a higher Ca/K ratio in heart tissue and higher transpiration than did the 2 higher concentrations. Blackheart symptoms were more severe in the 1.2 atm. solutions than in the 4.8 atm., but not significantly different in the 1.2 and 0.3 atm. solutions.

Temperatures recorded between August 25 and September 5, 1966 at 8:00 a.m. prior to starting the mist indicated that temperature readings were slightly lower in the misted than the control plots. After 5 hours of misting the leaf temperatures were 2.4°C lower, hearts 1.2° lower, air in canopy 2.6° lower and nutrient solutions 1.8° lower in misted than control plots.

When transpiration was high, blackheart symptoms either remained relatively constant or increased (Fig. 1). Comparing growth rate to transpiration rate (Fig. 1), during periods of high transpiration growth rate in misted plots appeared to exceed that of control plots, while during periods of low transpiration growth rate in misted plots was as low as or lower than that in control plots.

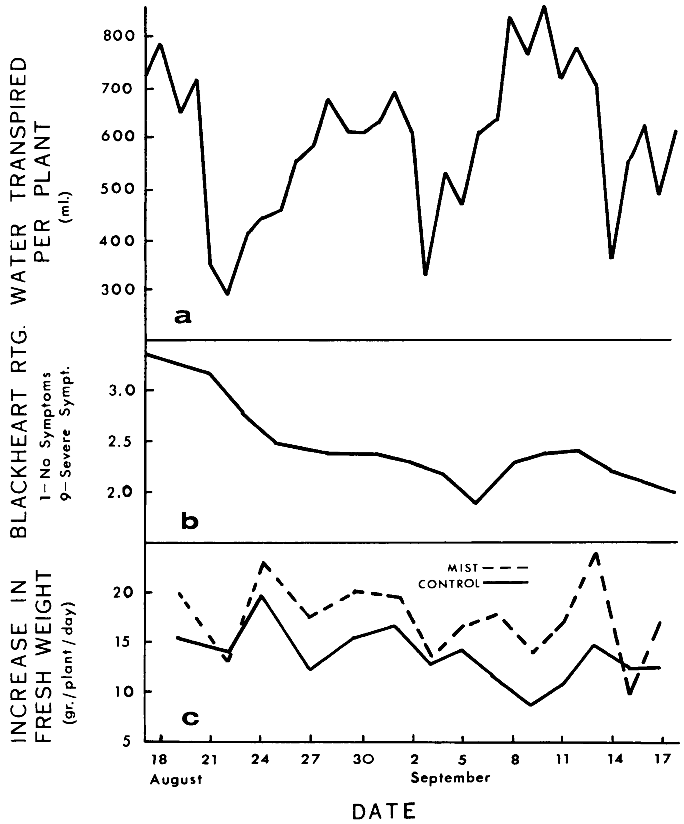

Fig. 1. The relationship between transpiration, blackheart rating and growth rate from August 17 to September 18, 1966. (a) Mean daily transpiration; (b) mean blackheart rating; (c) mean growth rates.

Discussion

Misting generally resulted in an increase in total fresh weight with no significant increase in dry weight because of a lower percentage of dry matter. The increase in fresh weight of misted plants was in agreement with results of other workers (4) who found increased growth due to reduced plant moisture stress. Sucker weight was also increased by mist applications, but there was no significant gain in marketable weight attributable to misting. Increased succulence associated with the lower percentage of dry matter may indicate a quality improvement in celery due to misting.

Reduction in the volume of water transpired per g of dry matter produced by the mist application compared to the control agrees with McMillan and Burgy (10). They found that transpiration was reduced proportionally to the evaporation of the sprinkled water. Reduction in transpiration however was not accompanied by a change in the Ca/K ratio in heart tissue. This is not in agreement with the findings of Freeland (7) who observed that higher transpiration caused corn and bean plants to take up relatively less Ca and more K. Based on the dry matter produced, misting reduced transpiration 20 and 27% in Experiments 1 and 2 respectively. These reductions may not have been great enough to cause marked changes in nutrient uptake. It is possible that by reducing the transpiration rate for only 7 hrs per day, ample time remained for the plants to regain their nutrient equilibrium. The infrared heat lamps increased the transpiration rate per g of dry matter produced. As for the mist application, Ca and K uptake was not altered significantly.

The simple linear correlation coefficients indicate that blackheart increased in severity with increasing total top fresh weight, increasing sucker weight and decreasing percentage of dry matter. This agrees with the reports of other workers (1, 8) who found that blackheart severity increased with increasing vigor. Misting increased fresh weights and decreased percentage of dry matter, yet did not result in a corresponding increase in blackheart severity. Possibly, the lower moisture stress on the misted plants minimized the development of necrotic tissue.

As the Ca/K ratio increased in the nutrient solutions, the Ca/K ratio in the hearts generally increased and blackheart symptoms decreased. These observations agree with those of Geraldson (8).

The volume of water transpired per g of dry matter produced was lowest in the lowest Ca/K ratio solution and highest at the highest Ca/K ratio and approximately equal in the medium ratio solutions (Table 1). Biebl (2) found that highly unbalanced K applications reduced transpiration which may have been the case in the low Ca/K ratio solution. The low K in the high Ca/K ratio may have caused the low water use efficiency (13).

The 0.3 atm. and 4.8 atm. solutions produced inferior growth compared to 1.2 atm. Deficiencies of some elements could have occurred because of depletion in the 0.3 atm. solutions. This could also explain the reduced water-use efficiency of this treatment (13). The high osmotic concentration could have resulted in less growth because of plant moisture stress as reported by other workers (6).

The present study indicates that misting during periods of high transpiration increased plant fresh weight yet prevented an increase in blackheart symptoms associated with increased plant size and succulence. Misting did not affect Ca and K content recorded at the end of the test periods. Highest top fresh weight and succulence occurred in the lower Ca/K ratio solutions and in the 1.2 atm. solutions. These conditions, however, were more conducive to blackheart.

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Inheritance in *Pisum sativum* L. of a Symptomless Response to Infection by Pea Streak Virus[1]

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Abstract. Pea cultivars may be severely or mildly affected (susceptible), or completely symptomless (resistant) when infected with an Oregon isolate of PSV. Infected plants of susceptible and resistant cultivars contained substantial virus concentrations which were not consistently related to symptom severity. The severity of symptoms in inoculated plants and the numbers of plants showing symptoms differed in various tests, apparently in response to changes in environment and the virulence of the virus. When apparent maximum symptom expression occurred, it was shown that the highest degree of resistance was due to a single recessive gene. Deviations from the expected ratio of 3 susceptible: 1 resistant (symptomless) were always the result of excess symptomless plants, probably because of combinations of effects of the environment, modifying genes from one or both parents, and in the later phases of the study, a reduced virus virulence. Observations and limited tests suggested that symptom development was promoted by conditions which were unfavorable for optimum plant growth.

Tests of pea (*Pisum sativum* L.) cultivars and breeding lines for resistance to isolates of pea streak virus (PSV) have usually resulted in severe symptoms or death of the plants. Similar results were found with isolates of alfalfa mosaic virus and clover yellow mosaic virus (1). In 1964 certain breeding lines inoculated with an Oregon isolate of pea streak virus (PSV-331) failed to develop symptoms. Tests were started, using F_2 populations on hand, to determine the inheritance of this apparent immunity. Assays for the virus, however, on a susceptible cultivar showed that the symptomless plants actually contained PSV. The ease of transfer to susceptible cultivars suggested the virus was present in a high concentration. Because this symptomless reaction appeared to be a potentially useful form of resistance which was consistent in all tests, inheritance studies were continued and expanded through more crosses. Limited investigation of factors affecting symptom expression was also undertaken.

Genetic control of variations in virus symptom expression in peas has been reported by Yen and Fry (5), who showed that resistance to pea mosaic virus was conditioned by a recessive gene, designated *mo*. The heterozygote, Momo, gave a delayed response to inoculation, but MoMo and Momo could not be clearly separated. Johnson and Hagedorn (2) found that resistance to pea mosaic isolate 1 of bean yellow mosaic virus was due to a single recessive gene, and suggested that a similar delay in symptom expression in the heterozygote occurred in their material. Schroeder. et al. (4) found that some strains of bean yellow mosaic virus produced symptoms in the heterozygote Momo only at high temperatures. Disease expression in the resistant genotype, momo, and the susceptible genotype, MoMo, was not affected by temperature.

Resistance to pea enation mosaic virus was found by Schroeder and Barton (3) to be due to a single dominant gene. In that case the resistant plants were able to grow and produce normally even though systemically infected by the virus.

Materials and Methods

The virus strain. The strain of pea streak virus used in this study was designated PSV-331. Originally taken from commercial peas in Western Oregon, it was classified as pea streak virus by R. E. Ford and R. O. Hampton by means of virus particle morphology, serology, host range, and physical properties.

Pea cultivars. Cultivars which did not develop symptoms even though systemically infected with the pea streak virus strain were considered to have resistance. The terms "symptomless" and "resistant" are used interchangeably. The principal commercial cultivars involved in this work, 'Midfreezer', 'Wiwo', 'Dark Gray Sugar', 'Freezer 37', 'Early Frosty', 'Perfection 3040', 'Dark Skin Perfection', and 'Perfected Freezer 60' ('PF 60') are susceptible to PSV-331. The breeding lines OSU 42, OSU 176-2, OSU 644, and the lines listed as parents in Tables 2-5, are resistant to PSV-331 and to pea enation mosaic virus.

General methods of plant culture and inoculation. Pea plants were usually grown in the greenhouse in gallon cans, in a mixture of silt loam and sand, with complete fertilizer added. Night temperatures were maintained at 65°F, while day temperatures ranged from a setting of 70° to 80°F or higher in sunny weather. In a field planting, cultivars were grown under

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