SOME FACTORS ASSOCIATED WITH THE DEVELOPMENT OF PITH IN WINTER GROWN EVERGLADES CELERY[1]

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INTRODUCTION

The development of pith in celery petioles continues to be of concern to celery growers although it has been recognized as one of the major factors in celery quality for more than fifty years.

Sayre (16) described pith as a breakdown in the parenchyma tissue and listed it an important quality factor. A great deal of work was done during the period 1925 to 1940 on factors affecting the development of pith in stored celery (3, 6, 14, 15, 17, 18, 19). Phosphorus treatments (14) in one case, nitrogen, phosphorus and potassium (6) in another, and potassium (3) were found to affect the keeping quality of celery in storage. Some studies, however, found no relationship between nutritional conditions and pith development in storage.

Coyne (7) also describes physiological pith development as "collapse of the parenchyma cells of the petiole." He further describes the malady as developing first at the extreme base of the outer petioles and in that portion of the leaf stalk above the first node. As the disorder continues, the entire petiole becomes pithy and progresses with petiole age toward the heart. He classifies the tendency of several celery varieties to develop pith as, Emerson Pascal > Summer Pascal > Utah 52-70 > Utah 15 > Utah and concludes that varieties with smaller parenchyma cells tend to be less pithy, which he attributes to the water retention capabilities of the smaller cells.

Several writers have stressed the influence of environmental conditions such as moisture supply, temperature fluctuations, etc., on the development of pith in field grown celery, but none seem to have demonstrated nutritional effects on the development of pith in the field.

Everglades celery growers in past years seemed to be of the opinion that excessive nitrogen fertilization was an important factor in increasing the tendency to develop pith. They often spoke of the condition as "blowing up" the crop with nitrogen. However, experimental results (4) (11) seemed to indicate that part of the problem may be the early onset of maturity and that treatments tending to delay maturity might delay the development of pith.

MATERIALS AND METHODS

Experiment Number 1: The objective of this experiment was to determine the effects of $NaNO_3$, NH_4NO_3 and $(NH_4)_2SO_4$, each applied at rates of 0, 75, and 150 pounds of N per acre, on relative growth and occurance of certain physiological disorders, particularly the development of pith, in largely winter grown Utah 52-70 celery. The experimental design was a split-split-plot. Three harvest dates, on week before estimated optimum maturity, at optimum maturity, and one week after estimated optimum maturity were main plots. Nitrogen sources were sub-plots, and nitrogen rates were sub-sub-plots. The experiment was transplanted November 5, 1959 and harvested February February 1, 8, and 16, 1960.

Basic fertility: This experiment was conducted on relatively new Everglades organic soil, having had one crop of celery the previous season. A broadcast fertilizer mixture was applied supplying 140 pounds P, 267 pounds K, 3.1 pounds Mn and 1.9 pounds B per acre. Soil samples taken 35 days after transplanting showed an average pH of 6.01 with 28 pounds H_2O soluble P and 192 pounds 0.5 N acetic acid soluble K per acre. Two equal sidedress applications, including the nitrogen fertilizer materials, were given 40 and 63 days after transplanting which supplied an additional 35 pounds of P and 200 pounds of K per acre.

Climatological conditions: Rainfall, recorded at the Everglades Experiment Station, was 8.16, 0.47 and 0.11 for November and December, 1960, and January 1961, compared to a 36 year average of 2.27, 1.69 and 1.86, respectively. Average mean daily temperatures were 71, 63 and 63° F. for the same months compared to a 36 year average of 69, 65 and 64° F., respectively. Heavy

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rains of 3.04, 1.52, and 1.44 inches occurred on November 18, 19 and 21 (12). The remainder consisted only of light showers that scarcely wet the surface of the soil. Temperatures dropped to 33°F. on November 30, 32 and 27° F. on the nights of January 23 and 23, respectively. In general temperature conditions were about normal for the season.

Experiment Number 2: The objective of this experiment was to determine the effects of frequency of nitrogen applications, again at 0, 75 and 150 pounds N per acre, all as ammonium nitrate, on relative growth, and the development of pith in fall and winter grown 52-70 celery. The experimental design was also a split-split-plot. The three harvest dates were main plots. Frequency of nitrogen applications, applied all at once 36 days after transplanting, in two equal applications 43 and 57 days, and in three equal applications 36, 51, and 67 days after transplanting were sub-plots. Nitrogen rates were sub-sub-plots. This experiment was transplanted September 27-28 and harvested December 20 and 27, 1960 and January 2, 1961.

Basic fertility: This experimental area, relatively new, was cropped to celery seedbeds for two years, and an early set of beds were grown on the area in summer of 1960, prior to the establishment of this experiment. Following the removal of plants from the beds in August, 1960, the area was drained, ditched, leveled, and moled in late August and pumps for water control installed. Fertilizer was broadcast containing 128 pounds of P, 486 pounds of K, 20.6 pounds Mn, and 9.2 pounds of B per acre. Soil samples taken 35 days after transplanting showed an average pH of 6.94, with 12 pounds of H_2O soluble P and 288 pounds of 0.5 *N* acetic acid soluble K per acre. Forty-four days after transplanting, a supplemental application of phosphorus was banded in the form of 18 percent P_2O_5, giving an additional 64 pounds of P per acre.

Climatological conditions: Rainfall was considerably below normal. A rain gage on the plot accumulated 3.14 inches through the duration of the experiment. The only rainfall of any consequence was 1.50 inches recorded October 10, 1960. Mean monthly temperatures for October through December, 1960 were 76, 71, and 61°F. (13) compared to a 37 year mean of 75, 69, and 64°F., respectively. The only severe temperatures were minimums of 34°F. the nights of December 17, 18 and 22, 1960.

Plot size: Sub-sub plots as treated, in both experiments, consisted of three 24 inch rows of celery, 40 feet in length, with plants set 7" apart in the row. Thirty feet of the center row was harvested for yield and pith data, consisting of 51 $\pm$ 1 plant per harvested sub-sub-plot.

Method of determining pithiness: Since pith development starts at the base of the oldest and outermost petioles, a quantitative method of rating for pith was obtained by cutting the plant at soil level and gathering all the petioles in one hand, slicing them off about 1½ inches from the end of the stem, and counting the number of petioles with the white pith showing. To get quantitative data on yield, weight and other data, it was necessary to modify this procedure by field trimming to a compact marketable plant. Following this, randomly selected plants were chosen, the butt sliced off as previously described, and number of petioles left with pith development counted. Thirty plants per plot were evaluated in this manner in *Experiment Number 1*, and 25 plants per plot in *Experiment Number 2*. It was felt that this procedure of evaluating pith gave a good quantitative estimate of differences.

Chemical methods: a. Soil analysis. Soil pH, phosphorus and potassium determinations were made in the routine soil testing laboratory at the Everglades Experiment Station (8).

b. Plant tissue analysis: Five groups of healthy outer petiole samples were taken in *Experiment Number 2* at 15 or 16 day intervals beginning at 35 days following transplanting and continuing to the last harvest. Nitrate N was extracted in $CuSO_4$-$AgSO_4$ solution with a Waring blendor (9), and determined colorimetrically with phenoldisulfonic acid. Total N was determined on dry material by the microkjeldahl method with salicylic acid used to insure complete nitrate reduction. Alcohol insoluble N, an estimate of large molecular protein N, was also determined by the micro-Kjeldahl method, after samples had been extracted for 24 hours in a Soxhlet apparatus with 70% ethyl alcohol. Phosphorus and the bases were determined from samples wet ashed with nitric-perchloric acid. Phosphorus was determined colorimetrically by the molybdivanadophosphate method (10). Potassium was determined with the flame photometer, and calcium and magnesium by the Versene method (5).

RESULTS

For *Experiment Number 1*, nitrogen sources x rate interactions were not significant, or in

Table 1. Exp. No. 1. Number pithy petioles per plant after field trimming, total and trimmed weights in pounds per plot.

Days from transplanting	No. pithy petioles/plant Rate of N, lbs./A.				Total fresh weight Rate of N, lbs./A.				Trimmed weight Rate of N, lbs./A.			
	0	75	150	Avg.	0	75	150	Avg.	0	75	150	Avg.
88	3.4	3.0	2.3	2.9	110	124	126	120	72	81	83	78
95	6.3	5.7	4.9	5.6	145	144	148	146	100	98	99	99
102	7.1	5.9	4.8	5.9	156	164	164	161	98	105	106	103
				(b)**				(a)**				(b)*
Avg.	5.6	4.9	4.0		137	144	146		90	95	96	
			(a)**				(b)**				(b)**	

(a) Significant linear response.
(b) Significant quadratic response.
* Significant or exceeding the .95 level but < .99 level.
** Significant at or exceeding the .99 level.

Table 2. Exp. No. 2. Number of pithy petioles per plant after field trimming and total and trimmed weight in pounds per plot.

Days from transplanting	No. pithy petioles/plant Rate of N, lbs./A.				Total fresh weight Rate of N lbs./A.				Trimmed weight Rate of N lbs./A.			
	0	75	150	Avg.	0	75	150	Avg.	0	75	150	Avg.
83	5.0	3.5	2.8	2.7	79	88	88	85	59	65	64	63
90	7.2	6.6	6.2	6.7	84	101	108	98	61	72	75	69
97	7.3	6.4	5.8	6.5	91	107	117	105	63	74	79	72
				(b)**				(a)**				(a)*
Avg.	6.5	5.5	4.9		85	99	104		61	70	72	
			(a)**				(b)**				(b)**	

(a) Significant linear response.
(b) Significant quadratic response.
* Significant at or exceeding the .95 level but < .99 level.
** Significant at or exceeding the .99 level.

Table 3. Exp. No. 2. Maturity changes in outer petioles, of percent dry weight and several nutritional components, given as percent of dry weight.

Days from transplanting	Nitrogen rate	Percent dry wt.	Total N	Protein N	NO_3-N	P	K	Ca	Mg
35	0	5.62	1.51	0.62	0.85	.325	7.07	3.07	.374
	75	5.65	1.58	0.65	0.72	.356	7.31	3.23	.382
	150	5.80	1.61	0.65	0.79	.331	7.25	3.23	.398
	Avg.	5.69	1.57	0.64	0.79	.337	7.21	3.18	.385
50	0	4.91	1.65	0.65	0.89	.454	7.73	2.99	.395
	75	5.17	1.71	0.66	1.04	.424	7.85	2.87	.384
	150	5.05	1.83	0.70	1.03	.428	7.87	2.84	.377
	Avg.	5.04	1.73	0.67	0.99	.435	7.82	2.90	.385
66	0	4.53	1.21	0.59	0.49	.448	7.75	3.36	.466
	75	4.44	1.44	0.55	0.80	.426	7.41	2.80	.395
	150	4.48	1.68	0.67	0.93	.481	8.08	3.02	.438
	Avg.	4.48	1.44	0.60	0.74	.452	7.75	3.06	.433
81	0	4.42	0.84	0.50	0.19	.380	5.93	3.14	.478
	75	4.37	1.16	0.66	0.45	.402	7.14	3.06	.469
	150	4.41	1.36	0.64	0.66	.403	6.28	2.76	.448
	Avg.	4.40	1.12	0.60	0.43	.395	6.45	2.99	.465
96	0	4.36	0.74	0.33	0.02	.316	5.32	2.96	.421
	75	4.23	1.12	0.40	0.14	.321	5.45	2.51	.380
	150	4.22	1.22	0.42	0.39	.326	5.14	2.37	.366
	Avg.	4.27	1.03	0.38	0.18	.321	5.30	2.61	.389
		(b)**	(c)**	(c)**	(c)**	(b)**	(b)**	(c)**	(c)**
	Averages for Nitrogen rates, all sampling periods.								
	0	4.77	1.19	0.56	0.49	.385	6.76	3.10	.425
	75	4.77	1.40	0.58	0.63	.386	7.03	2.89	.402
	150	4.79	1.54	0.62	0.76	.394	6.92	2.84	.405
		N.S.	(a)**	(a)*	(a)**	N.S.	N.S.	(a)**	(b)*

(a) Significant linear response for averages.
(b) Significant quadratic response for averages.
(c) Significant cubic response for averages.
* Significant at or exceeding the .95 level but < .99.
** Significant at or exceeding .99 level.

a few cases were significant at low levels only. The large differences are those concerned with nitrogen rates. For *Experiment Number 2,* designed to test frequency of application and N rates, effects of frequency of nitrogen applications were not significant. Few application dates x rates interactions were significant, and then only at low levels. For the purposes of this paper only the effect of harvest dates and nitrogen rates are considered.

Harvest data for *Experiment Number 1 and Number 2* are given in Tables 1 and 2. Total fresh weight data indicated that the plants continued to gain some fresh weight between the second and third harvests, although gains were smaller the second week than the first for both experiments. Previously published data (4) indicates that celery in this area grows rapidly the last three to four weeks and may double its weight during this period. This has also been reported by Zink (20), who found that direct seeded celery in California would double its weight in approximately the last 21 days before optimum maturity. The former study indicated winter celery grown in the Everglades of Florida at maturity may rather suddenly stop growth for a period, stand dormant for a few days, then start to increase in fresh weight again. All these data seem to indicate that the estimated optimum harvest date for these plots may have been about 3 to 4 days premature.

The growth response to nitrogen obtained in these two experiments is not new. Growth responses of winter grown celery to nitrogen on these soils have been reported for many years (1) (2). The maximum growth response under the conditions of these experiments seems to have been at about 75 pounds of nitrogen per acre. However, the responses in delaying the development of pith was a linear decrease in both experiments from 0 to 150 pounds N per acre.

Analytical data for some nutritional constituents of the older and outer petioles where pith development starts are given in Table 3. Sampling started 5 weeks after transplanting when plants were just starting to grow. The first group of samples were taken before any supplementary nitrogen was applied. Percent dry weight of petiole tissue declined from the first sampling; nitrogen content, highest at the 50 day sampling period, declined even where high rates of nitrogen had been applied. Phosphorus and potassium content of these outer petioles increased from the 35 to 66 day sampling period, after which there was a general decline to the 96th day. There was a sharp lowering of calcium and magnesium content in these older pithy petioles from the 81 to 96 day following transplanting. The decrease in protein and NO_3-N was especially pronounced between the 81st and 96th day.

Discussion and Conclusions

Hall *et al.* (11) found that the celery petioles lost dry weight, alcohol insoluble solids, chlorophyll, reducing sugar, total sugars, and crude fiber in both outer and inner petioles at maturity, which corresponded to the check in growth found in the field (4). After about 10 days both outer and inner petioles seemed to regain these constituents. Zink (20) used entire plants rather than plant parts in his work and found similar trends in dry weight, N, P, Ca and Mg content as that given for outer petiole tissue in Table 3.

From the citations mentioned above, and the data presented here, it appears that the development of pith in field grown celery must be connected with the phenomena of reproduction in this normally biennual plant. At a certain stage of growth, fresh weight accumulation seems to cease (4). This may be also brought about earlier by conditions that check growth such as fluctuating temperatures, drought conditions (7) or possibly by depletion of certain nutrients from the root zone, as nitrogen. There tends to be a movement out of the petioles of elaborated organic materials (11) and mineral constituents as shown here, consequently breakedown of the parenchyma cells as described by Sayre (16), Coyne (7) and others.

It is widely known that large amounts of nitrogen tend to keep most plants vegetative, and delay the reproductive process. This seems to have been the case in these experiments, and the effect seems to have been one of delay of maturity. From the evidence presented one deduces that in field grown winter celery in the Florida Everglades, aside from uniform moisture control during the latter part of the growing season, one of the best controls for the development of pith will be those nutritional balances that keep the plant vegetative for as long a period as possible.

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EFFECT OF AGE OF PLANT ON EARLINESS AND YIELD OF CANTALOUPES STARTED IN PEAT POTS

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Most commercial cantaloupe plantings are direct-seeded and thinned to the desired row spacing. Seeding is usually done in the spring after the danger of frost is past. In order to plant earlier and thus produce earlier fruit some growers have resorted to the use of such containers as paper bands, wood-veneer bands, fiber pots, etc. Consequently plants can be started 3 to 4 weeks early and then set in the field. In recent years the use of peat pots has become popular. These pots, made of compressed raw peat, have some nitrogen and other nutrients incorporated into them and are excellent for growing any plant that is to be later set in the field. Since the walls of the pot are easily penetrated by roots, the plant and container may be set in the ground, thus minimizing root injury and saving labor required when bands must be removed before the plant is set.

Because of the uncertainty of spring frost occurrence in south Florida cantaloupe growers prefer to field-seed very early and at the same time to plant seeds in peat pots placed in a protected bed area. If the field-seeded plants are later killed by frost, the grower then resets the field, using the plants already established in the containers. If the field-seeded crop survives, part of the pot-grown plants are used to reset the missing hills and the remainder set in an area prepared for them. So the question facing the Florida grower is, how long can plants be held in peat pots and still be set in the field with an expectation of a normal yield?

Loomis (1) found that cucurbits are generally hard to transplant. As a result of a series of transplanting experiments covering several seasons, he reported "increasing injury with age of plant after four weeks: cabbage, tomato, lettuce and cauliflower showed an increase of 33.6 percent while cucumber, melons and corn showed an increase of 57.1 percent." He concluded that, "observations on the structure of older roots of a number of vegetable plants indicated that the roots of some of the more difficultly transplanted vegetables are suberized or cutinized at an early age either in the endodermis or periderm layer. This may mean that the older roots of these plants are ineffective in water absorption while similar roots of tomatoes, for instance are capable of a limited amount of absorption during the period immediately following the removal of root tips in transplanting. Branch formation in shortened roots seems also to be inversely proportional to the extent to which suberization has progressed." Romshe (3), as a result of four seasons tests, reported that muskmelons grown in the greenhouse in asphalt-coated paper or wood-veneer bands and then transplanted to the field two weeks later showed a significantly greater yield than that obtained from field-seeded plants. Harvest from transplants also started approximately two weeks earlier. Pierce and Peterson (2) in trials with muskmelons tested row spacing, seeding date and plant container. Although they tested three ages of plants in peat and paper containers, the interval between sowings was only five days with an interval of five days between the last sowing and field setting. The check was field-seeded at the time pots were set in the field. Container-grown plants always gave larger and earlier yields than field-seeded plants.

An experiment conducted in the spring of 1962 to test the response of cantaloupes grown in peat pots to planting dates is reported in this paper. The experiment reported here demonstrates the length of time a cantaloupe plant

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