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FIELD APPRAISAL OF CELERY GROWTH

J. O. STRANDBERG[1]
IFAS, University of Florida
Agriculture Research and Education Center
Sanford, FL 32771

Additional index words. plant growth, *Apium graveolens.*

Abstract. **The number of leaves and petiole length of celery (*Apium graveolens* L. *dulce*) from production fields in Florida varied less between seasons and locations than fresh or dry weight and plant height. The coefficients of variation of the slopes of curves for log-fresh weight and dry weight were 0.22 and 0.27, respectively. Coefficients of variation for plant height, petiole length, and number of leaves were 0.34, 0.20, and 0.16, respectively. In small plot experiments, the above growth variables were highly correlated with each other (>0.90), but plant spacing affected plant height and petiole length more than number of leaves. Leaf initiation rate experiments demonstrated that once plants had recovered from transplanting, rates of leaf initiation per day were stable. Expression of leaf initiation rates in leaves per degree hour showed less variation than leaves per day when weather was erratic or cold weather fronts were encountered. The number of leaves has the best potential for monitoring celery growth.**

Celery is an intensively cultured vegetable crop which lacks easily discernable growth and development stages during seedbed and field production. Appraisal of celery growth in the field is useful to monitor crop performance, to project harvest dates, and to determine the need for crop and pest management activities. For these purposes, the assessment of relative plant size may not be sufficient. Rates of plant growth and development which can be compared to expected values may be more useful to crop managers.

Traditional methods of plant growth analysis offer one approach to monitor celery growth (7), but these methods require extensive sampling and sample processing efforts such as determination of dry weight. Such methods are likely to exceed the resources of crop and pest managers. The growth of celery has been studied from several practical viewpoints. Zink (12) measured rates of celery growth by measuring the accumulation of fresh and dry weight over time and related these rates to nutrient uptake by celery plants. Burdine et al. (2) measured increases in total fresh weight of celery during approximately 7-day intervals beginning 70 days after transplanting and continuing until harvest. On each sampling date, they also measured number of leaves present on harvested celery plants that were trimmed to a marketable size. Mishoe et al. (8) developed a growth model for celery which accounted for leaf and petiole dry weight and number of leaves. Predicted values using the model agreed well with field observations.

A close relationship has existed between fresh and dry weight accumulations and other growth variables. Pest or crop management applications may often require phenological or developmental as well as growth information. Stone et al. (10) described the growth and development of celery plants in relation to the application of insect control measures; insecticides were crucial when petioles were initiated that would appear on the harvested product. In a similar study, Musgrave et al. (9) measured celery leaf initiation and leaf longevity to help decide the best times to take action against pests and to protect petioles that would be likely to appear on the harvested product. This study was directed toward Integrated Pest Management (IPM) applications. Both of the above methods depended on measurement of leaf numbers at intervals of about one week.

Cannel et al. (3) evaluated celery growth by measuring the elongation of petioles to provide a relative measure of growth that could be used to evaluate crop performance and effects of cultural inputs. In effect, Cannel et al. measured the length of the tallest leaf (leaf tip to crown) at fixed intervals during the growing season. They related plant height (length of tallest leaf) to the fresh weight of celery plants and obtained good correlation between these values. They concluded that plant height might be used as a simple yet effective measure of growth. Trumble et al. (11) have used the number of leaves and plant height to evaluate responses of celery plants to the leafminer (*Liriomyza trifolii*) and to control measures used against it.

In this study, plant height, fresh weight, dry weight, number of leaves, and leaf area were studied as indices of relative growth. Variables easily measured in the field were

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[1]Professor (Plant Pathologist).

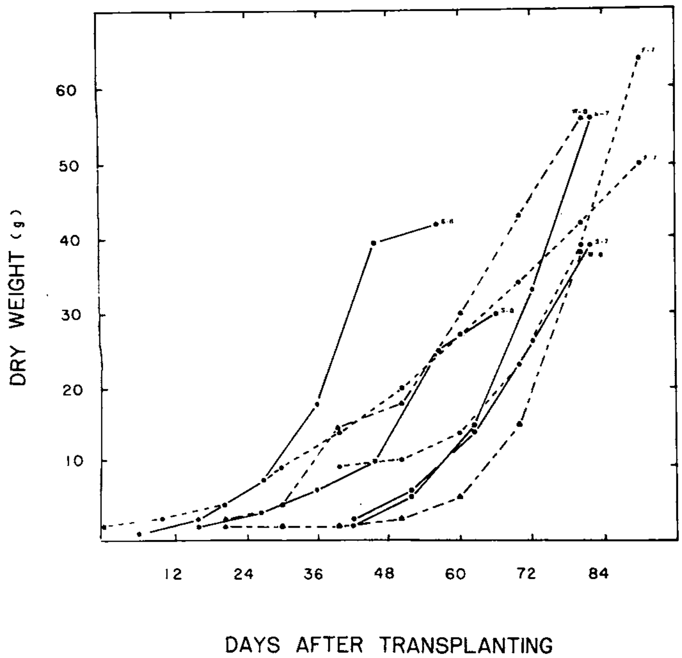

Fig. 1. Dry weight (g per plant) of celery grown at different locations and in different production years and seasons in central Florida. Codes: F = fall, W = winter, S = spring; Production season numbers 6, 7, 8, refer to 1976, 77, and 78. Example, W-8 = winter 1978.

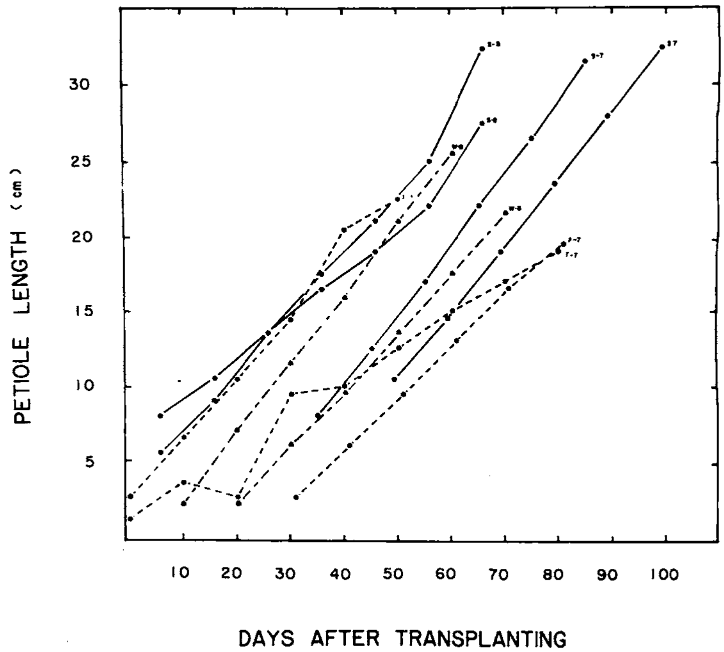

Fig. 3. Length of celery petioles during crop growth at different locations and during different production years and seasons in central Florida. Codes: F = fall, W = winter, S = spring; Production season numbers 6, 7, 8, refer to 1976, 77, and 78. Example W-8 = winter 1978.

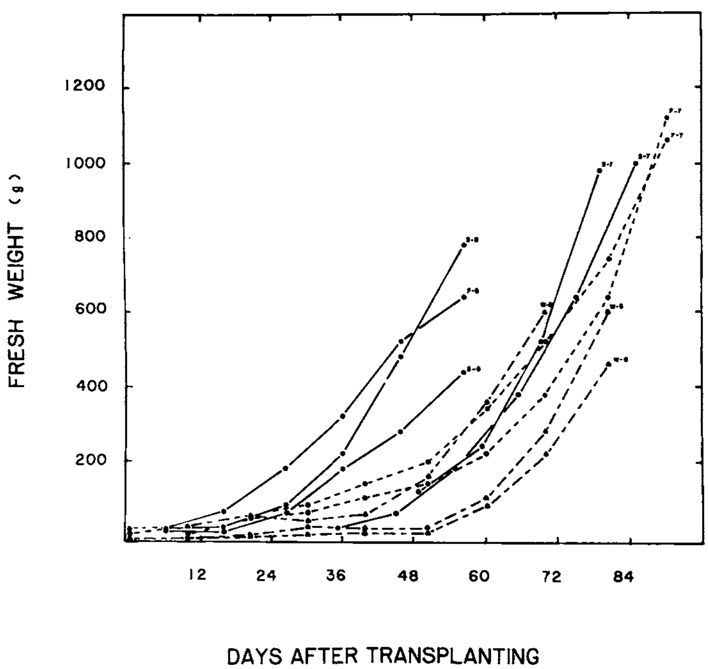

Fig. 2. Fresh weight of celery plants (g per plant) grown at different locations and in different production years and seasons in central Florida. Codes: F = fall, W = winter, S = spring; Production season numbers 6, 7, 8, refer to 1976, 77, and 78. Example, W-8 = winter 1978.

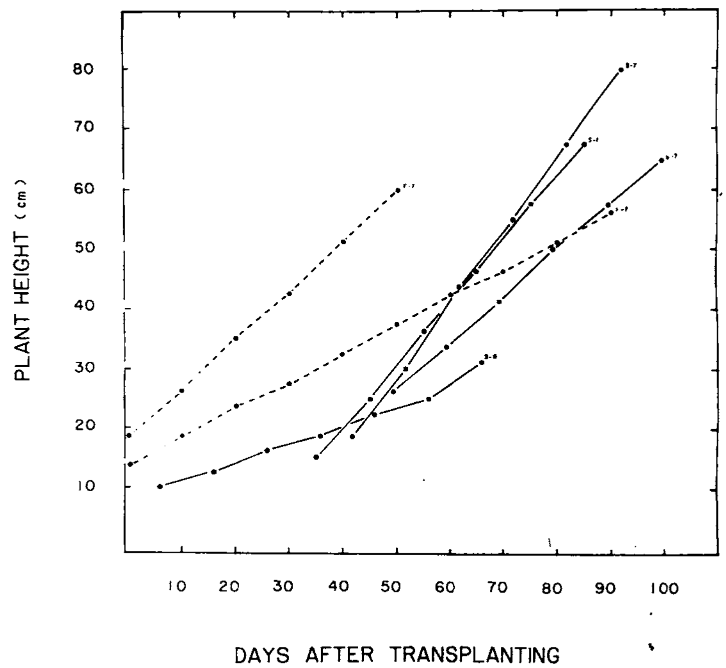

Fig. 4. Height to topmost leaflet of the largest leaf of celery plants following transplanting for celery grown at different locations and in different seasons and years in central Florida. Codes: F = fall, W = winter, S = spring; Production season numbers 6, 7, 8, refer to 1976, 77, and 78. Example, W-8 = winter 1978.

compared with fresh and dry weight accumulation to see if they reflected presently used indices of celery growth. Degree hours and days after transplanting were also compared for use in expressing leaf initiation rates.

Materials and Methods

Celery growth was measured in commercial production fields from samples of Florida 2-14 celery growing at Belle Glade and Zellwood over a 3-year period (1976-1979). The plants were collected and measured as part of a celery IPM scouting program. Plants were selected at random from within 7- to 10-ha celery production blocks at 7-day intervals beginning 7-14 days after transplanting and continuing until harvest. Ten plants per production block were cut at the soil level and placed in plastic or fiber-mesh bags and evaluated within 3-4 hr after acquisition. Dry weight

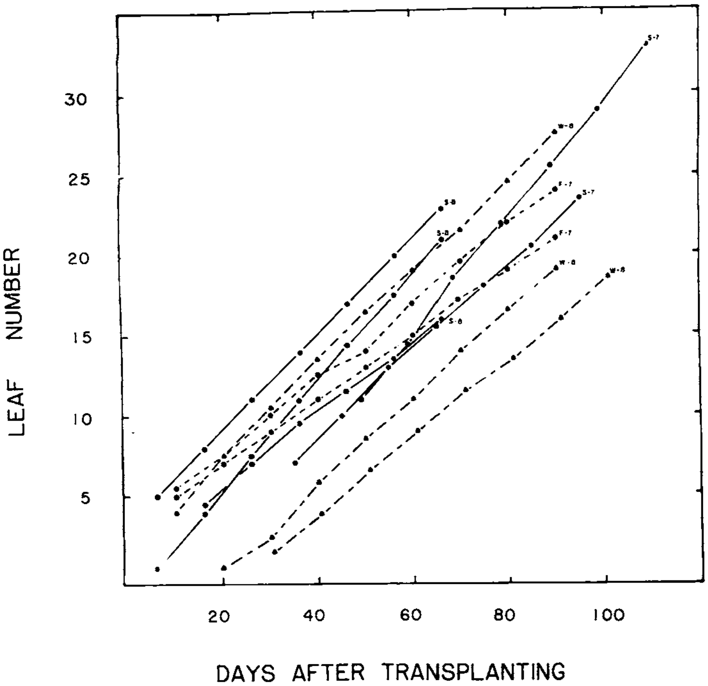

Fig. 5. Number of leaves per celery plant during crop growth at different locations and in different years and seasons in central Florida. Codes: F = fall, W = winter, S = spring; Production season numbers 6, 7, 8, refer to 1976, 77, and 78. Example, W-8 = winer 1978.

was determined by spreading plant parts on trays, drying them in a warm greenhouse for 24 hr, followed by drying at 110°C for 24 hr. Petiole length was measured on the longest leaf from the point of petiole attachment in the crown to the node where the first leaflets were attached to the petiole. Plant height was measured from the point of petiole attachment in the crown to the tips of the terminal leaflet of the tallest leaf. Number of leaves were determined by removing and counting leaves per plant down to the youngest leaf emerging (but not expanded) from the bud. Leaf area was measured with a leaf area meter (Model LF-3000, LiCor Instruments, Lincoln, NB).

For detailed growth measurements, celery plants were transplanted into small plots and grown under conditions to simulate commercial celery production. Plots were planted on February 23, 1977, on organic soil (Lauderhill muck) at Zellwood, Fla., and sampled beginning on 1 Mar., then weekly thereafter. Plants were transplanted at 2 spacings: 24 cm in-the-row and 90 cm in-the-row in rows spaced 90 cm apart. Plots consisted of 8 rows, 30 m long. On each sampling date, 10 plants were selected at random from each plot area and evaluated with methods described above. The plots were sampled until 3 May. Degree hours were calculated with the method of Allen (1).

Numbers of leaves initiated over time were also measured in small replicated plots. Celery plants cv. Florida 2-14 were transplanted into 6 x 12 m concrete frames filled with 30 cm of an organic soil (Lauderhill muck) at Sanford, FL. Plants were placed 20 cm apart in rows spaced 76 cm apart. Plants were fertilized 3 times at approximately 3-week intervals with an application of 20-8.8-16.6 N-P-K fertilizer (at a rate of approximately 34 kg/ha) and watered with overhead irrigation as required. Transplants had 3-4 leaves when obtained from a commercial grower, but most of the leaves had been severely trimmed. The youngest new leaf emerging from the bud was arbitrarily considered leaf number 1. This leaf and succeeding leaves were tagged with plastic tape bearing the leaf number and date of emergence. Plants were examined daily and newly emerging leaves were recorded and tagged. Plants were transplanted on 5 Oct. 1982, and the last leaf counts were made on 9 Jan. 1983. Degree hours per day were calculated as previously described.

Results and Discussion

The dry weight and fresh weight of celery plants varied more than petiole length, and number of leaves, but less than plant height over 3 growing seasons and several locations. The shape and slopes of the curves varied greatly between seasons and locations (Figs. 1-5). Curves for fresh and dry weight were not linear and could not be directly compared (Figs. 1-2). Coefficients of variation of the curves of the log of fresh and dry weights were 0.22 and 0.27, respectively. Curves for plant height, petiole length, and number of leaves were linear and were directly compared (Figs. 3-5). The coefficients of variation among the slopes of the curves were 0.34, 0.20, and 0.16 for plant height, petiole length, and number of leaves, respectively. The coefficient of variation for plant height was the largest among those calculated (0.34). Coefficients of variation for log fresh and dry weight were smaller (0.22 and 0.27) and were comparable to those of petiole length (0.20) and number of leaves (0.16). The coefficient of variation for number of leaves was the smallest obtained. The variation among measurements of petiole length and number of leaves from one crop to another was approximately the same as for fresh and dry weight. These results provided good evidence that the number of leaves or petiole length can be more useful and reliable indices of celery growth.

In replicated plot studies of celery growth employing 2 plant spacings, fresh weight, dry weight, leaf area, plant height, petiole length, and number of leaves were all highly correlated with each other for each of the plant spacings ($P > 0.90$). Thus, for some purposes, any of these variables may be appropriate to measure relative growth in a specific production field and season. The plant spacing treatments affected fresh and dry weight, but also affected leaf area, plant height, and petiole length much more than number of leaves (Fig. 6). These results are in agreement with the field scouting data (Figs. 1-5).

In this experiment, plant height was greatly affected by plant spacing. Although celery plant height has been proposed as an index of growth, Cannel et al. (3) showed that plant height was greatly affected by fertilizer treatments. Guzman et al. (5,6) used both plant height and number of leaves to measure celery growth and concluded that number of leaves might be more suitable for IPM scouting (6), but they did not present data or support this view.

Francois and West (4) found that soil salinity greatly affected plant height and yields, but did not affect number of leaves on trimmed celery. Trumble et al. (11) found that the level of leafminer damage as influenced by insecticide treatments had large and significant effects on the height of celery plants. Moreover, the type of celery transplant used by Trumble et al. (container grown or bare-rooted) also had a significant effect on plant height. They also obtained large differences in leaf numbers (apparently number of leaflets per plant) and lesser differences in number of petioles (leaves) per plant among their treat-

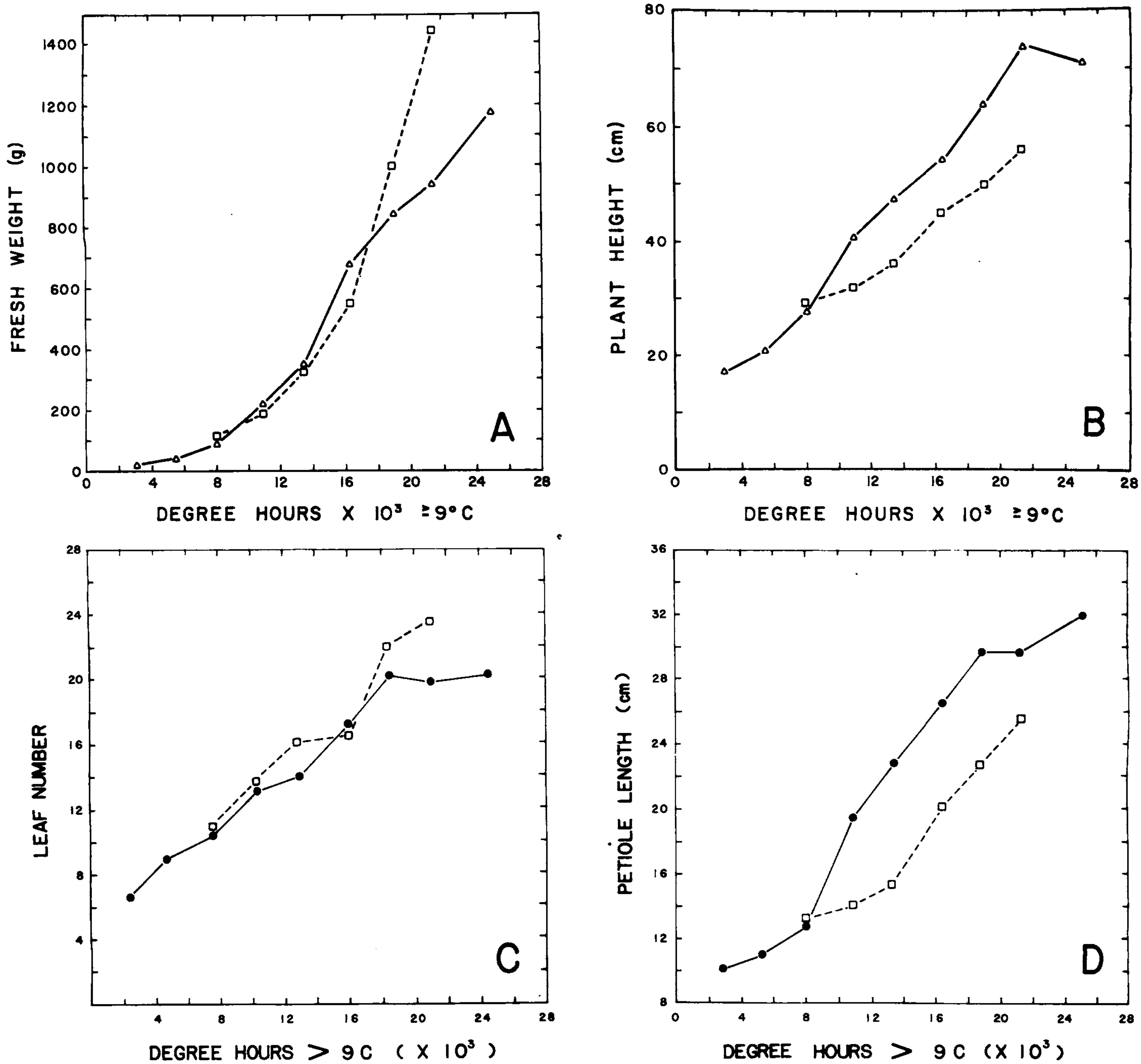

Fig. 6. Celery growth variables plotted against degree-hours after transplanting at two plant spacings. A) fresh weight in g per plant, B) plant height, C) number of leaves per plant, and D) petiole length. Plant spacing at 24 × 90 cm —o— and 90 × 90 cm —■—.

ments. The differences between numbers of leaves were smaller than the other differences, but were significant. Thus, plant height is clearly a variable which can be expected to vary greatly under different growth conditions as well as plant stress conditions. Number of leaves can also vary under stress conditions, but from the results of this study do not vary greatly from one cropping situation to another under normal growing conditions.

The number of leaves provided a reliable and predictable index of celery growth (Figs. 7,8). When plotted in terms of days after transplanting, leaf initiation rates were low immediately following transplanting (5-7 days between leaves); however, the rate of leaf initiation increased to approximately one leaf per 3-5 days as plants developed and this rate continued at a fairly constant level until a harvestable size was attained (Fig. 7). The standard deviations of the measurements were relatively large following transplanting, but dropped to a lower and steady level which continued for most of the growth period then increased as harvest approached.

It has previously been determined that the lower growth temperature threshold for celery was approximately 9°C (author, unpublished, and 8). Thus, degree hours accumulated above 9°C were calculated for the period of the experiment. Leaf initiation periods were plotted in terms of degree hours (Fig. 8). Results were similar to rates expressed as leaves per day (Fig. 7); however, the advantage to the degree-hour basis to express

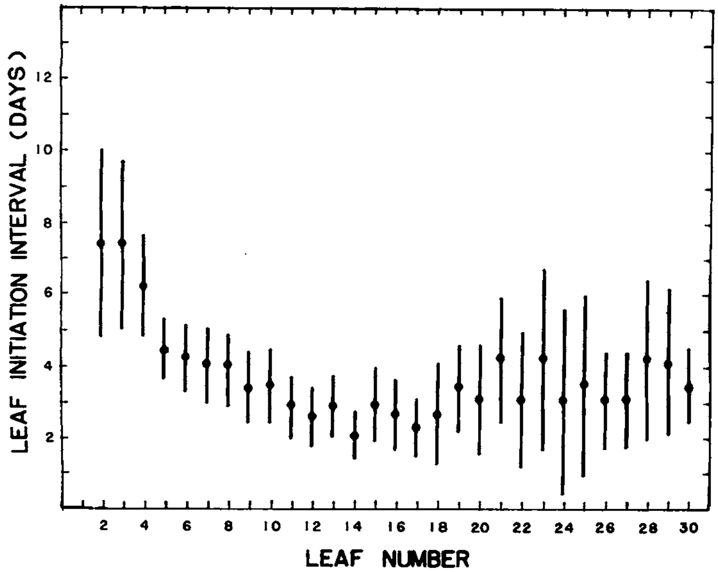

Fig. 7. Intervals of leaf initiation for celery measured in days with standard deviations of the means. (Average for 25 plants.)

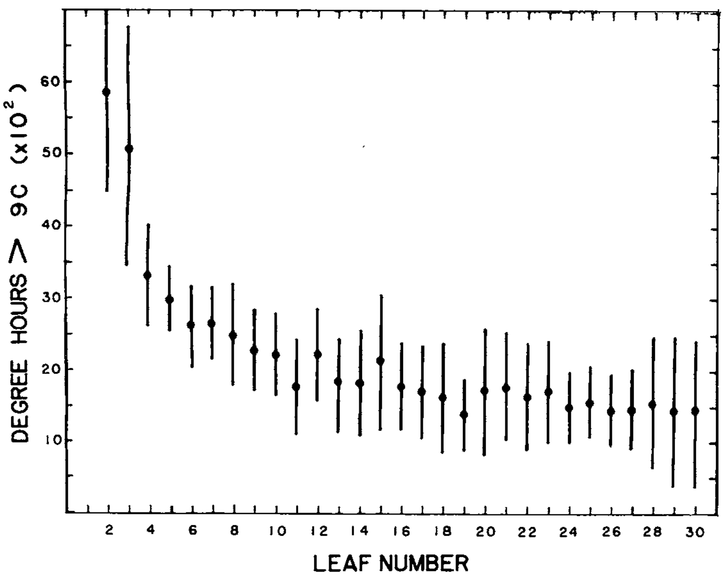

Fig. 8. Intervals of leaf initiation for leaves measured in terms of degree hours above 9°C with standard deviations of the means. (Average for 25 plants.)

leaf initiation rates became evident during the period when leaves 18-26 were initiated. During this period, a series of cold weather fronts produced large fluctuations in daily ambient temperature (Figs. 7,8). When leaf initiation rates were expressed in degree hours per leaf, the standard deviation of the measurement of leaf initiation times was greatly reduced during this period.

To compare the degree hour and days per leaf approach to measure leaf initiation rates, the coefficient of variation was calculated for each set of data. Both approaches to estimating leaf initiation rates produced approximately similar coefficients of variation throughout the crop growth period except during the period of unfavorable weather (Fig. 9). During this period, the degree hour method produced much lower coefficients of variation. Standard deviations and coefficients of variation for

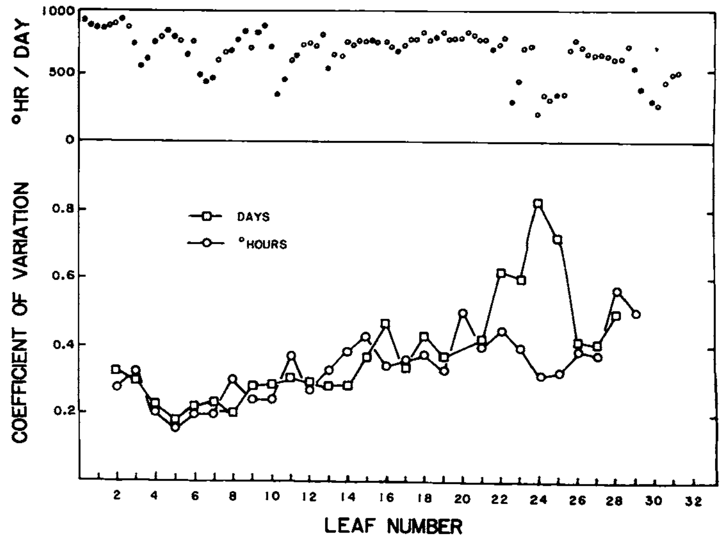

Fig. 9. Coefficients of variation for celery leaf initiation intervals expressed in days —■— and degree hours above 9°C —o— along with degree hours accumulated per day during the approximate corresponding periods of leaf initiation at Sanford, Florida.

both the degree hour and days per leaf method increased as leaf number exceeded 25. This was probably due to the decreasing number of leaves in the samples because few plants produced more than 25 leaves.

When a large number (25) of plants were observed at daily intervals and the leaves initiated during those intervals carefully noted, leaf initiation plotted against time or degree hours produced a smooth curve. The portion of the curve covering the period between 2-3 weeks after transplanting and harvest size was approximately a straight line. This agrees well with field data obtained through IPM scouting from several locations and from several seasons (Fig. 5).

The number of leaves per plant measured at appropriate intervals after transplanting can provide a reliable index of celery growth which can be directly compared with expected results or historical data. The number of leaves per plant is easily obtained by field scouting and is relatively insensitive to small changes in weather and crop environment, but is affected by serious plant stress. In conjunction with accumulated heat units (degree-hours >9°C) leaf initiation rates can provide a useful appraisal of celery growth.

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DOUBLE CROPPING STRAWBERRIES WITH VEGETABLES

E. E. ALBREGTS AND C. M. HOWARD
IFAS, University of Florida
Agricultural Research & Education Center
Rt. 2, Box 157
Dover, Florida 33527

Additional index words. Fragaria x *ananassa,* sweet corn, cucumber, squash, and snap bean.

Abstract: **Sweet corn, squash, cucumber, and snap bean were double cropped on strawberry beds immediately after fruit harvest ceased. Paraquat was applied to beds to destroy all vegetation prior to planting the second crop each season. In 1981, mulch remained on beds and fertilizer was applied at either 0, 30-13-25, or 60-26-50 lb./acre N-P-K. In 1982, polyethylene mulch was removed from one-half of the plots. Sweet corn was fertilized at 60-24-50 or 120-48-100 lb./acre N-P-K whereas cucumber, squash, and snap beans received 30-12-25 lb./acre N-P-K. In 1983, all mulch was removed from beds, and crops were seeded at 2 densities. Sweet corn was fertilized at 50-24-48 or 100-48-96 lb./acre N-P-K; cucumber and squash received 25-12-24 or 50-24-48 lb./acre N-P-K. The initial levels of soluble salts at saturation in ppm were 550 in 1983, 3300 in 1982, and 1700 in 1981 except with cucumber beds which had 2400. Yields increased linearly with fertilizer rates with all crops except cucumber in 1981. Fertilizer rates in 1982 did not affect yields, (probably as a result of the high fertilizer carryover) but squash yields increased with use of mulch. Only cucumber yields were affected by treatments in 1983, when the 2x fertilizer rate and the 12-inch plant spacing gave highest yields. All crop yields were in the range of state averages. Soil soluble salt concentrations were generally positively correlated with fertilized rates only early in the season. In 1982, beds covered with mulch maintained higher levels of soil soluble salts all season than the unmulched beds.**

About 5,000 acres of strawberries are grown on polyethylene-mulched beds each year in Florida (2). The strawberry harvest season generally ends in April and a late spring crop of vegetables is possible before seeding a cover crop. The mulched and previously fumigated bed can serve a dual purpose provided nematodes, diseases, and insects are controlled. Production costs can be lower with a second crop since fumigation may not be needed and the bed is already made and mulched (3).

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The purpose of this study was to evaluate the effect of mulch, fertilizer rates, and plant spacing on double cropping of vegetables on strawberry beds.

Materials and Methods

Experiments were conducted during 3 spring seasons following winter crops of strawberries. Each September the strawberries were fertilized with 200-44-186 lb./acre N-P-K. One-fourth of the fertilizer was applied broadcast and the remainder was placed one inch deep in a band in the bed center. Beds were fumigated with a mixture of methyl bromide and chloropicrin applied at 400 lb./acre of bed area. Immediately after fumigation, the beds were mulched with 1.25 mil black polyethylene. Strawberry plants were set in Oct. on the 24 inches wide × 6 inches high beds. Planting slits were 11 inches apart down the row and 12 inches apart between rows. A few days after the final strawberry harvest, plants were sprayed with paraquat, and, in the plots to be planted to sweet corn and snap bean, the plant tops were also removed. Sweet corn ('Silver Queen'), squash ('Yellow crookneck'), cucumber ('Poinsett') and snap bean ('Harvester') were seeded in 15-ft plots in April or early May. Snap bean (2 seasons only) and sweet corn were seeded 2 rows per bed, and squash and cucumber were seeded one row per bed. Cucumber and squash were seeded between the fertilizer band and the strawberry plant row. Fertilizer was applied twice each season to all plots. During the first season, the mulch remained on the bed, and fertilizer was applied at either 0, 30-12-25, or 60-26-50 lb./acre N-P-K. Fertilizer was placed in holes 4 inches deep in the center of bed at 12-inch intervals. Snap bean and sweet corn were seeded in previous strawberry planting slits with 2 plants of bean and one of corn per slit. Cucumber plants were spaced 12 inches and squash 18 inches apart. During the second season, the polyethylene mulch was removed from one-half the plots, and fertilizer was applied at either 30-12-25 or 60-24-50 lb./acre N-P-K except for corn, which received double these rates. Polyethylene was slit 6 inches from the plants and fertilizer was applied in a 2-inch deep trench. Plant density was the same as for the previous year. During the third season, all mulch was removed and the corps were fertilized at either 25-12-24 or 50-24-48 lb./acre N-P-K except for corn, which received double these rates. Corn was seeded at spacing of 8 or 15 inches; cucumber at spacing of 6 or 12 inches, and squash at spacing of 9 or 18 inches.

Soil samples were taken 3 times each season: prior to planting, between fertilizer applications, and at the end of