Growth Stage, Flowering Pattern, Yield, and Harvest Date Prediction of Four Types of Cucumber Tested at 10 Planting Dates

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Abstract

   Cucumber (*Cucumis sativus*) is a major vegetable crop worldwide. Compared with many crops, cucumber reaches harvest stage rapidly. Computer growth models have been developed to help researchers, growers, and processors predict plant development and harvest date. The objective of this study was 1) to study growth and development of cucumber using both days after planting and cumulative heat units (HU) to determine their value in prediction of harvest date for pickling cucumbers grown in North Carolina, and 2) to study vegetative and flowering patterns from planting to harvest. The experiment was a split-plot treatment arrangement in a randomized complete block design with three replications. Plantings were made every week for 10 weeks (30 April through 2 July). Four cultigens were chosen to represent a range of types. Data on plant growth stage and weather conditions were collected daily. Main growth stages were planting (direct seeding), emergence, vine tip over, flowering, and fruit harvest. Heat units were calculated from weather data using a model with the daily maximum air temperature, a base temperature of 15.5°C, and a reducing ceiling of 32°C. 'Calypso' was the earliest maturing cultigen, M 21 and Wis. SMR 18 were intermediate, and WI 2757 was the latest. Plantings made early in the season required more days to reach fruiting stage than those made later. Heat units were more stable over planting dates than days after planting. 'Calypso' had more branches per plant and more nodes per branch than the dwarf-determinate cultigen M 21. Early yield was correlated with number of branches/plant and nodes/branch. Additional research is needed to improve the heat unit model so that it predicts harvest date accurately regardless of planting date.

INTRODUCTION

   Cucumber (*Cucumis sativus*) is a major vegetable crop in North Carolina, with the second largest production of pickling cucumber, and the third largest production of slicing cucumber in the U.S. (United States Department of Agriculture, 2001). Cucumber develops rapidly, with a shorter time from planting to harvest than for most crops. However, the number of days to harvest changes with temperature, making it difficult to predict.

   Computer growth models have been developed for crop production systems, providing a means for organizing what is known about their growth and development. An example of a model that has been used successfully for soybean studies is SOYGRO (Wilkerson et al., 1983; Jones et al., 1991). Prediction of growth stage and harvest date have been used to improve crop management. Uses include scheduling labor and machinery, integrated pest management practices, and timely production for high market prices (Perry and Wehner, 1996).

   Most cucumber cultivars grown before 1980 were monoecious. In monoecious cultivars, the staminate flowers are produced first (nodes 1 to 9), followed by an alternating staminate-pistillate stage, and finally, a continuous pistillate stage (Shifriss, 1961; Tasdighi and Baker, 1981). Yield is dependent on pollination, since fruits develop after bees pollinate the pistillate flowers, unless the plant is parthenocarpic. Now, most

cultivars of pickling and slicing cucumber used in the U.S. are gynoecious hybrids. Gynoecious plants usually have a ratio of pistillate to staminate flowers of 9:1 (McMurray and Miller, 1969). Gynoecious cultivars intended for field production are blended with a monoecious hybrid or inbred to provide the pollen necessary for fruit set, with 10 to 15% monoecious plants being optimum (Miller, 1976). Gynoecious hybrid cultivars and mechanical harvesting make harvest prediction for cucumber even more important for harvest scheduling and grower profitability.

A heat unit model has been developed for cucumber (Perry et al., 1986; Perry and Wehner, 1990) that predicts harvest date for cucumbers grown under different conditions. Other models (Chen et al., 1975; Haffar and Van Ee, 1990) have been developed to solve additional production problems.

The objective of this study was to compare days after planting and cumulative heat units to determine their value in prediction of harvest date for pickling cucumbers grown in North Carolina. Further, we were interested to determine the relationship between yield and vegetative traits such as branch number, node number, and percentage of pistillate nodes.

MATERIALS AND METHODS

All experiments were conducted at the Horticultural Crops Research Station, Clinton, N.C. Plantings were made every week for 10 weeks (30 April through 2 July). The experiment was a randomized complete block design with three replications and a split plot treatment arrangement. Whole plots were 10 planting dates and subplots were four cultivars and breeding lines (cultigens). The four cultigens 'Calypso', M 21, 'Wis. SMR 18', and WI 2757 were chosen to represent groups of interest to breeders, including inbreds vs. hybrids, new vs. old releases, anthracnose resistant vs. susceptible, and early vs. late maturity.

Plots were seeded on raised, shaped beds in rows 1.5 m apart. Plots were 6 m long separated by 1.5 m alleys at each end and were thinned to 60 plants per plot (64,556 plants/ha). The soil type in the study was a mixture of Norfolk, Orangeburg, and Rains (fine-loamy, siliceous, thermic, Typic Kandiudults) with some Goldsboro (fine-loamy, siliceous, thermic, Aquic Paleudults). Recommended horticultural practices (Schultheis, 1990) were used for all experiments. Fertilizer was incorporated before planting at a rate of 90-39-74 kg/ha (N-P-K), with an additional 34 kg/ha N applied at the vine tip over stage. Curbit (ethalfluralin N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoro-methyl) benzenamine) was applied for weed control. Irrigation was applied when needed for a total (irrigation plus rainfall) of 25 to 40 mm per week. 'Sumter' pollenizer was planted in side rows and end plots to provide additional pollen and border competition for the test plots. No disease problems were observed.

Data on plant growth stage and weather conditions were collected daily. Main growth stages were emergence (50% of plants at cotyledon stage), vine tip over (50% of plants had top leaves touching soil), flowering (50% of plants with flowering), and fruit harvest. Harvest stage was further divided into 5, 25, 50, and 75% fruit yield from six harvests. Total yield was the sum of six harvests, and early yield was the sum of the first two harvests. Heat units were calculated from weather data using the method of Perry et al. (1986), which uses the daily maximum air temperature, a base temperature of 15.5°C, and a reducing ceiling of 32°C:

If maximum air temperature (Max)$\leq$32°C, then HU=Max-15.5;

If maximum air temperature (Max)>32°C, then HU=[32-(Max-32)]-15.5.

Vegetative traits were measured at first harvest, including branches/plant, node of branch location, nodes / branch, and number of staminate and pistillate flowers. All plots were harvested when 50-mm-diameter fruit were first observed in the experiment. Plots were harvested twice weekly for three weeks. Fruit were graded as marketable or cull, and weighed to get marketable yield. Marketable yield was highly correlated ($r = 0.99$) with total yield (marketable + cull), so data on total yield data were not presented in the figures and tables. Early yield was fruit weight in the first two harvests. Data were

analyzed as plot means using SAS (SAS Institute, Inc., Cary, N.C.) for analysis of variance, regression, and correlation.

RESULTS AND DISCUSSION

Planting dates and cultigens had highly significant effects on days and heat units for predicting growth stage and harvest date. There was no interaction between planting date and cultigen for days or heat units. There were significant differences among cultigens for all growth stages. M 21 required the most days from emergence to tip over and the fewest from tip over to flowering (Fig. 1). 'Calypso' had the fewest days from planting to emergence and emergence to tip over. WI 2757 required the most days from tip over to flowering and the fewest for flowering to 5% harvest.

There were significant differences among planting dates for all growth stages. In general, number of days from planting to emergence was highest for the early planting dates and decreased for the later planting dates. Growth stages were reached in fewer days for the later planting dates, with the exception of tip over to flowering, which was more variable, and increased slightly for later planting dates (Fig. 1). 'Calypso' required 64 days to reach 100% fruit harvest for planting date 1 vs. 40 days for planting date 10. The trend was similar for the other cultigens, except that WI 2757 was later maturing, requiring 3 and 2 days longer at planting dates 1 and 10, respectively. M 21 and Wis. SMR 18 were intermediate in maturity.

There was a large difference in the number of days required to reach the different growth stages, with emergence to tip over requiring the greatest time, followed by planting to emergence. Flowering occurred almost simultaneously with tip over, especially for the early planting dates (Fig. 1). M 21 required more days to reach tip over because of its dwarf plant habit, which allowed it to remain upright longer. On the other hand, M 21 required fewer days from tip over to flowering stage than the other cultigens.

Compared with days from planting, heat units were more independent of planting date. Cultigens planted early in the season required more heat units to reach 100% fruit harvest (Fig. 2). For example, 'Calypso' required 680 HU for planting date 1 vs. 585 HU for planting date 10. As a result, the cumulative heat unit for each cultigen had a downward trend in which cultigens planted early in the season required more heat units than when planted late in the season (Fig. 2). Thus, the heat unit model does not account for all major factors controlling time to harvest in cucumber.

The four cultigens differed in the number of days and HU required to reach a particular growth stage. 'Calypso' was the earliest maturing cultigen and WI 2757 was the latest (Fig. 2). For example, 'Calypso' required 64 days at planting date 1, while WI 2757 required 67 days at planting date 1 to reach 75% fruit harvest (Fig. 2).

Number of nodes per branch was greatest on the lower (earlier) branches, so branch length was probably dependent on the amount of time since formation (data not shown). The number of branches per plant and nodes per branch (measured at first harvest) was lowest at the intermediate planting dates (Table 1). The tall indeterminate cultivar Calypso had the most branches and nodes, and the dwarf determinate inbred M 21 had the least.

Correlation of vegetative traits with marketable yield was low and not significant (data not shown). However, some correlations of vegetative traits with early yield were significant (Table 1). 'Calypso' had a significant correlation of early yield with number of nodes/branch, indicating that early yield was higher when the plants were able to grow longer branches having more nodes (and leaves). Early yield of 'Wis. SMR 18' was correlated with branches/plant. Early yield of M 21 was correlated with branches/plant and nodes/branch. Early yield of WI 2757 was not correlated with any vegetative trait. Thus, increased early yield was correlated with increased branches, nodes, both, or neither in the four cultivars. Perhaps, stressful environments limited the growth of some cultigens, resulting in smaller plants and lower early yield.

In conclusion, heat units were more reliable for predicting the growth stage of different types of cucumbers than the method of counting days after planting. However,

additional research is needed to improve the heat unit model so that it predicts harvest date more accurately regardless of planting date. Vegetative traits were associated with yield, especially early yield, but only in certain cultigens. It appears that some cultigens achieve high early yield with branching ability, while others achieve it with more nodes (leaves). Finally, there are some cultigens where higher yield was associated with both extra branches and nodes.

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Tables

Table 1. Vegetative and yield traits for four cultigens of cucumber planted at 10 planting dates (weeks) in Clinton, North Carolina.[1]

Treatment effect	No. Branches /plant	No. Nodes /branch	Pistillate nodes (%)	Early Fruit (%)	Marketable Fruit (%)	Yield, Mg/ha Early	Marketable
Planting date							
1	4.0	3.6	60	10	82	2.9	19.7
2	5.3	4.5	54	22	83	6.8	28.3
3	2.5	2.9	54	20	81	5.5	23.1
4	3.3	3.2	66	21	81	4.3	18.2
5	1.4	1.4	79	12	81	1.7	12.5
6	1.9	2.3	67	14	76	1.2	6.5
7	3.1	3.0	65	18	85	3.3	16.9
8	2.4	2.1	48	9	81	1.5	10.8
9	3.5	3.9	51	25	77	4.1	12.0
10	4.3	4.6	50	54	75	6.1	9.5
Cultigen							
Calypso	3.9	3.9	84	37	83	8.7	23.6
M 21	2.6	2.2	46	19	82	2.9	15.2
Wisconsin SMR 18	2.8	3.2	52	16	79	2.5	15.1
WI 2757	3.3	3.3	57	11	77	1.0	8.7

Correlation (r): early fruit yield vs. vegetative traits

Calypso	0.49	0.63*	-0.08
M 21	0.76*	0.81*	-0.45
Wisconsin SMR 18	0.70*	0.55	-0.12
WI 2757	0.40	0.50	-0.11

[1] Data are means of 3 replications and 6 harvests. Planting dates were weekly from 30 April - 2 July. Vegetative data were taken at first harvest. *indicates correlation significant at 5% level.
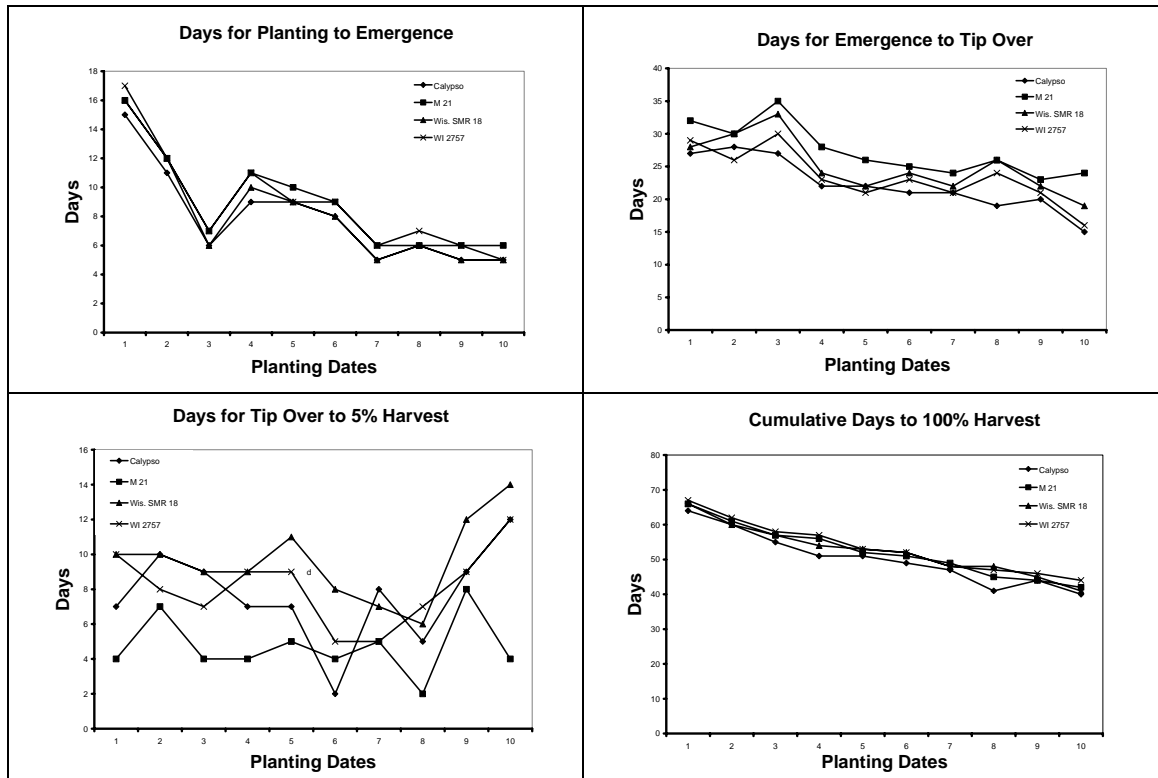
Fig. 1. Number of days required for each of four cultigens to progress from one growth stage to another for 10 planting dates in North Carolina. Planting dates were 1-week intervals from 30 April to 2 July. Data are means of 3 replications and 6 harvests.
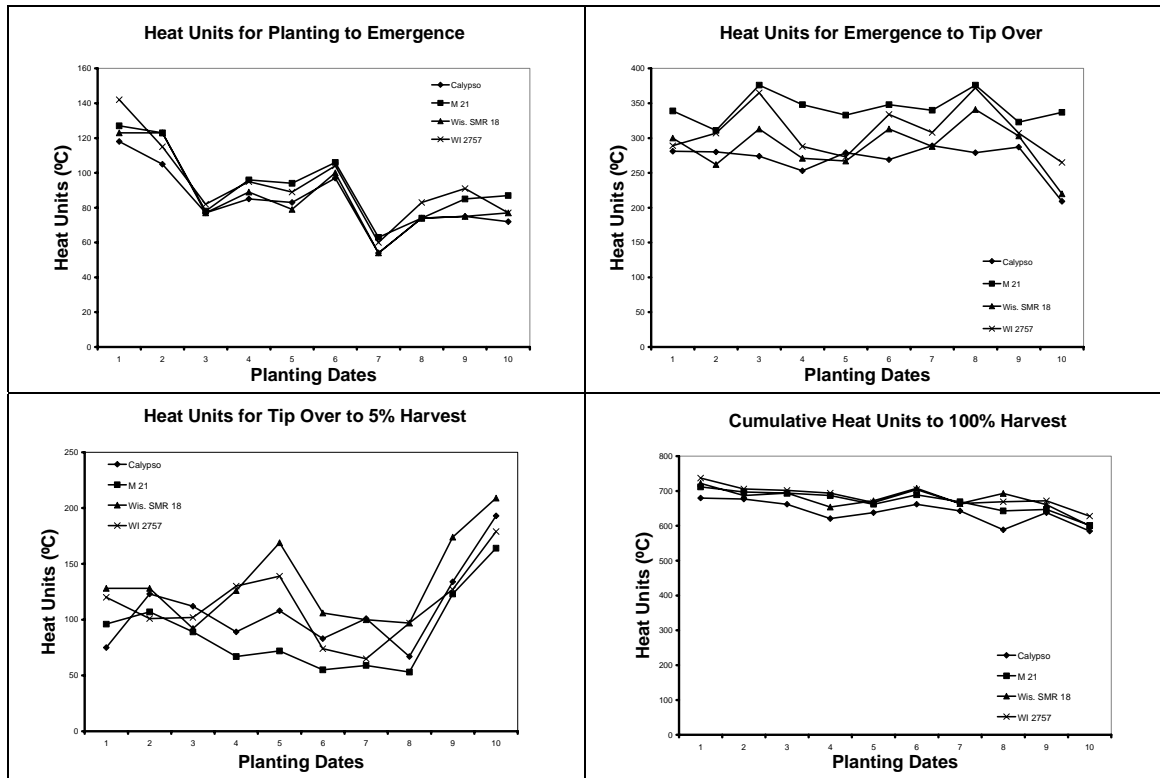
Fig. 2. Number of heat units required for each of four cultigens to progress from one growth stage to another for 10 planting dates in North Carolina. Planting dates were 1-week intervals from 30 April to 2 July. Data are means of 3 replications and 6 harvests.