A Heat Unit Accumulation Method for Predicting Cucumber Harvest Date

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Additional index words. growingdegree days

Summary. The use of a previously developed model for predicting harvest date in cucumber production systems is described. In previous research we developed a new method using daily maximum temperatures in heat units to predict cucumber harvest dates. This method sums, from planting to harvest, the daily maximum minus a base temperature of 60F (15.5 C), but if the maximum is >90F (32C) it is replaced by 90F minus the difference between the maximum and 90F. This method was more accurate than counting days to harvest in predicting cucumber harvest in North Carolina, even when harvest was predicted using 5 years of experience for a particular location and planting date.

A ccurately predicting harvest date and a crop's developmental stage has widespread application for improving crop management, e.g., scheduling labor, machinery, integrated pest management practices, and timely production at high market pricing. The concept of heat summation to achieve this prediction for vegetable crops dates back to 1929 when it was found that peas flowered after receiving a particular amount of heat, regardless of the number of days involved (Boswell, 1929). The research that followed focused on what we

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RESEARCH UPDATES

Planting date March

April

Table 1. Predicted heat unit (HU) accumulation harvest dat (DTH) for Clinton, N.

. Predicted heat unit (HU) accumulation, date, and total days from planting to harvest			Planting date		Harvest HU date			DTH	Planting date		нц	Harvest		DTU		
for gyr	wecious pic	ckling cuci	umber pla	anted in		28	774		16	49		30	2204	uate	10	41
, N.C.,	from 1 Mar	: to 2 Sept.				29	791		16	48	Inly	1	2204		10	41
						30	807		17	48	July	2	2256		12	41
g		Harvest			May	1	825		18	48		4	2308		12	41
0	HU	date		DTH	May	2	843	June	19	48		5	2335		15	41
1	149	May	21	81		3	861		19	47		6	2360		16	41
2	155	ivitay	21	80		4	878		20	47		7	2386		17	41
3	161		21	79		5	896		21	47		8	2412		18	41
4	168		22	79		6	914		21	46		9	2438		19	41
5	175		22	78		7	935		22	46		10	2464		20	41
6	182		22	77		8	954		23	46		11	2490		21	41
7	186		22	76		9	972		24	46		12	2516		22	41
8	192		23	76		10	988		24	45		13	2542		23	41
9	198		23	75		11	1006		25	45		14	2569		24	41
10	202		23	74		12	1028		26	45		15	2595		25	41
11	209		23	73		13	1050		27	45		16	2621		26	41
12	216		24	73		14	10/2		27	44		17	2647		27	41
13	225		24	72		15	1093		28	44		18	2674		- 28	41
14	237		25	72		10	1113		29	44		19	2701		29	41
15	247		25	71		17	1155	Tester	30	44		20	2/2/		30	41
16	256		25	70		10	1155	July	1	44		21	2/52	6	31	41
1/	262		26	70		20	11/0		2	43		22	2///	зерт.	1	41
10	200		26	69		21	1220		2	43		23	2802		2	41
20	2/3		20	08		22	1242		4	43		25	2855		3	41
20	201		27	67		23	1265		5	43		26	2883		5	41
22	290		27	66		24	1290		6	43		27	2909		6	41
23	301		29	66		25	1311		7	43		28	2936		7	41
24	308		28	65		26	1331		7	42		29	2962		9	42
25	315		28	64		27	1352		8	42		30	2988		10	42
26	322		29	64		28	1373		9	42		31	3015		11	42
27	328		29	63		29	1396		10	42	Aug.	1	3041		12	42
28	337		29	62		30	1420		11	42		2	3068		13	42
29	346		30	62	_	<u>31</u>	<u>1445</u>		12	42		3	3095		14	42
30	358		30	61	June	1	1471		13	42		4	3121		15	42
31	370		31	61		2	1496		14	42		5	3147		16	42
1	384		31	60		3-	1522		15	42		6	3173		17	42
2	397	June	1	60		4	1544		16	42		7	3200		19	43
3	412		1	59		5	1508		10	41		8	3227		20	43
4	428		2	59		7	1595		1/	41		9	3253		21	43
5	443		3	59		8	1645		10	41		10	2205		22	43
07	454		3	58		9	1670		20	41		12	2221		25	40
8	405		3	5/ 57		10	1696		21	41		13	3357		24	45
9	486		4	56		11	1719		22	41		14	3384		20	44
10	495		ŝ	56		12	1743		23	41		15	3409		28	44
11	506		5	55		13	1768		24	41		16	3436		29	44
12	521		6	55		14	1793		25	41		17	3462	Oct.	1	45
13	537		6	54		15	1818		26	41		18	3487		2	45
14	552		7	54		16	1844		27	41		19	3512		4	46
15	567		8	54		17	1869		28	41		20	3536		5	46
16	583		8	53		18	1894		29	41		21	3561		6	46
17	596		9	53		19	1919		30	41		22	3587		8	47
18	609		9	52		20	1946		31	41		23	3610		10	48
19	624	~	10	52		21	1972	Aug.	1	41		24	3637		11	48
20	641		10	51		22	1997		2	41		25	3662		13	49
21	657		11	51		23 24	2021		5	41		26	3088		15	50
22	673		12	51		24 25	2048		4 5	41		2/	3/10		17	51
23	690		12	50		25 26	2074		5 6	41 41		20 20	3/42 2749		19 1	52
24 25	707		13	50		27	2125		7	41 41		29	3708 2704		21	55 54
20 26	720		14	50		28	2150		8	41		30	2818		23 25	54
20	/ 37 755		14	49 40		29	2176		9	41	Sept	1	3842		23	55 56
41	/ 33		13	47							oopt.	$\hat{2}$	3868		29	57

now call growing-degree days.

Growing-degree days are determined by calculating the average of the maximum and minimum air temperature for a day and subtracting a base temperature, usually the minimum germination temperature for the crop. Because often more than 1 growing-degree day occurs on a given day (one 24-h period), the term growing degree days is confusing. Researchers have developed more complex methods of heat summation, and many now use the term heat unit (HU) to describe this concept.

Recently progress has been made in the development of weather-based (predominantly temperature) models that predict harvest or other developmental stages. It is assumed that, although moisture, fertility, and pest and disease incidence affect crop development, it is predominantly driven by temperature, which is linked to

moisture. This type of model addresses the timing of crop, disease, or pest development. It does not address yield or quality.

Recent efforts have incorporated techniques to improve the simulation of the diurnal temperature change. The original formula assigns half the day to the maximum temperature and half to the minimum temperature, when actually the temperature changes

Table 2. Target heat unit (HU) accumulation from planting to first harvest for pickling cucumber cultivars of two maturity groups.

Early season maturing, HU = 1053
Blitz
Calico
Calypso
Carolina
Cascade
Castlepik
Chemset
Commander
Earlipik 14
Explorer
Fremont
Greenpak
Gynomite
Lucky Strike
Medusa
Multipik
Panorama
Pikmaster
Pinnacle
Regal
Reliance
Salvo
Sampson
Score
Southern Belle
Tamor
Target
Tempo
Totem
Triple Crown
Triplemech
Midseason maturing, HU = 1125
Clinton
Pennant
Saladin
SMR 58
Sumter\
Triple Pak
Wisconsin SMR 18

throughout the day. New techniques have added the concept of ceiling temperatures, above which plant growth stops and reduced ceiling temperatures, above which plant growth declines.

Pickling and slicing cucumbers usually are harvested two to three times per week for 3 to 4 weeks in North Carolina. Harvests can be as few as once per week (Wisconsin), and extend as long as 10 weeks (Ohio, California). Also, once-over harvest of pickling cucumbers is common in areas with uniform production conditions (Michigan, Wisconsin, Delaware), but Table 3. Target heat unit (HU) accumulation from planting to first harvest for freshmarket cucumber cultivars of three maturity groups.

Early season, $HU = 1154$					
Lama					
Raider					
Revenue					
Slice King					
Slice Nice					
Slicemaster					
Sprint 440					
Midseason, $HU = 1246$					
Dasher II					
Castlemaster					
Centurion					
Cherokee 7					
Coolgreen					
Guardian					
Jet Set					
Medalist					
Slice Mor					
Verino					
Late season, $HU = 1337$					
Ashley					
Comanche 7					
Early Triumph					
Marketmore 76					
Marketsett					
· Pacer					
Poinmarket					
Poinsett 76					
Slice					
Super Slice					

this method of harvest results in a low percentage of small sizes. The trend in the past decade is to harvest fewer times in multiple-harvest systems, because new cultivars provide a more concentrated fruit set and because harvest costs are becoming a larger part of total production costs.

In previous research, in a comparison of 14 methods for determining heat unit requirements, Perry et al. (1986) determined that the most accurate prediction method was to sum, over days from planting to harvest, the difference between the daily maximum and abase temperature of 60F (15.5C), but if the maximum exceeded 90F (32C), it was replaced by 90F (32C) minus the difference between the maximum and 90F (32C), before subtracting the base. These base and ceiling values were determined from an analysis of five base and five ceiling temperature values. To determine the units for each day the following equations were used:

If maximum air temperature is 90F (32C), HU = max - 60F [1] If maximum air temperature is greater than 90F (32C), then HU = (90 - (max - 90)) - 60 [2]

In a subsequent independent test of this method, it was determined to be more accurate than counting days to harvest for processing cucumbers (Perry and Wehner, 1990).

To use this model in North Carolina, tables of daily normal HU accumulation, based on climatological data of daily maximum and minimum air temperatures of 1961-90 (Owenby and Ezell, 1992), and the associated harvest dates were developed for planting dates from 1 Mar. to 2 Sept. (Table 1). The table is designed for use with midseason, pickling-type cultivars, e.g., HU target of 1125. However, a correction factor should be used if the cultivar is of different maturity or is a slicing type (Tables 2 and 3). A lookup table may seem rather low-tech in the current computerized world, but its convenience supports this format for field applications. The table could be computerized.

The following procedure enables the user to update the harvest prediction based on observed daily air temperatures. First, calculate the HU for each day using Eqs. [1] and [2], above. Second, keep a running total of these HUs beginning on the planting date. Third, update the harvest date prediction by subtracting the current total from 1125. Add the result to the accumulated HUs from the table for the current day. Find the number closest to this result in the HU column of the table and read the associated harvest date. This is the updated harvest date prediction.

For example, using the sample table for the Clinton location, a midseason-maturing, pickling-type cultivar, and a planting date of 10 Apr. (Table 1), the initial harvest date prediction is 5 June. If a 25 Apr. update is carried out, and the HU accumulation on 25 Apr. is 400, then the predicted harvest date would change. Normally the total would be 723 - 495 = 228(note, the amount accumulated from 1 Mar. to 10 Apr. must be subtracted to get the units accumulated from 11– 25 Apr.):

- a) 1125 400 = 725.
- b) 723 + 725 = 1448.
- b) 723 + 723 = 1448.
- c) Closest number to 1448 is 1445.d) Updated harvest date is 31 May.

RESEARCH UPDATES

Any attempt to explain the entire developmental and maturation process of a particular cultivar using a temperature model alone is an oversimplification. Moisture, fertility, and pest and disease incidence, as well as the weather variables, certainly are involved in determining the crop's development rate. These factors are major determinants of yield and quality, but for HU modelling, temperature is assumed to be the major driver of growth rate. Results of current work show that HU modelling can be applied to operational systems.

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