Yield of Spring-Planted Cucumber Using Row Covers, Polyethylene Mulch, and Chilling-Resistant Cultivars

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North Carolina is a leading producer of field-grown cucumbers (*Cucumis sativus* L.) in the United States. In the 2001 to 2003, North Carolina ranked second in the production of processing (pickling) cucumbers, after Michigan, with approximately 74,700 Mg harvested per year. In the same period, North Carolina ranked fifth in the production of fresh-market (slicing) cucumbers (50,000 Mg per year) after Florida, Georgia, California, and Michigan (5).

In North Carolina, growers produce a spring and a summer crop. The primary production area is the coastal plain, where the spring crop is planted mid-April, approximately one month earlier than in the mountains, the secondary production area (3). Strategies to extend the production season of cucumbers in environments where chilling injury of the seedlings may occur, include the development of chilling resistant cultivars that can germinate at low soil temperatures and are resistant to chilling (low temperatures above freezing). In a study of environmental effects on response to chilling treatments in cucumber, chilling resistance was determined by growth temperature before chilling, chilling temperature and duration, light intensity during chilling, and genotype (4). Based on these results, the USDA-ARS cucumber germplasm collection was screened to rank PI accessions, cultivars, and breeding lines for resistance to chilling injuries (Smeets and Wehner, data not shown).

The use of polyethylene mulches in horticulture has been widely adopted for the control of weeds and the reduction of herbicide use (1). Polyethylene mulches are applied to cover raised beds, after incorporation of herbicides, while the soil between beds is kept weed-free through cultivation and herbicide applications. In addition, fumigation under the mulch strips may help to control weeds, although fumigations are done mostly to control soil-borne pathogens and nematodes.

Polyethylene mulches may also affect yield in horticultural crops, by increasing the soil temperature and the amount of light reflected from the soil onto the canopy. For example, the mulch surface color had a significant effect on total yield and earliness of fresh-market tomatoes, by influencing the plant microclimate and stimulating higher and earlier fruit production in this crop. The comparison of red, black, silver, and white mulch colors resulted in higher yields from plots with red or black mulch (2).

Row covers are commonly used for the production of horticultural crops when the average temperatures during the growing season are lower than the optimum for plant growth. There are two major types of row covers: polyethylene slitted film mounted on wire hoops and floating polyester. The major advantage of the second type is the easier installation system with a modified polyethylene mulch applicator. Even though these two types of row covers offer the best level of control for day-time temperatures, the night-time protection from frost that they provide is not as useful. Furthermore, the humidity level underneath the row covers determines the usefulness of these materials in different environments (6). The combination of mulch and row covers allows the improvement of soil and air temperatures, as well as weed control under the row covers. There is no need to remove the covers after their placement until the end of the protective treatment.

In our study of early production of pickling and slicing cucumbers in North Carolina, we verified the effect of black polyethylene mulch, clear slitted polyethylene or floating polyester row covers, and genetic resistance to chilling. Our objectives were: 1) to determine the best combination of mulch and row cover types for early production of chilling resistant and susceptible cucumbers, and 2) to evaluate a diverse group of chilling resistant and chilling susceptible cucumber cultivars and breeding lines in early spring production in North Carolina.

Methods

We conducted our experiments at the Horticultural Crops Research Station at Clinton, North Carolina. In 1987, we used two cultivars to evaluate the best combination of mulch and row cover for early production of cucumbers in North Carolina. 'Wisconsin SMR 18' was resistant to chilling, while 'Poinsett 76' was susceptible. In 1988, we used the best combination of mulch (black polyethylene) and row cover (floating nonwoven polyester) to trial a total of 14 pickling and 14 slicing cucumber cultivars and breeding lines for early production.

'Albion', 'Calypso', 'Castlepik', 'Chipper', Gy 14A, H-19, M 21, M 28, M 29, 'Pixie', 'Raleigh', 'Wisconsin SMR 18', 'Sumter', and 'Wautoma' were pickling cucumber cultivars. 'Ashley', 'Centurion', 'Dasher II', 'Early Triumph', 'Lemon', 'Mekty Green', 'Marketmore 76', 'Poinsett 76', 'Pacer', 'Palomar', 'Sprint 440S', 'Straight 8', 'Supergreen', and 'Tablegreen 65' were slicing cucumber cultivars. The chilling resistance of the cultivars used in this study was determined by Smeets and Wehner in previous experiments (unpublished data, personal communication).

We direct sowed on raised, shaped beds on 1.5 m centers. Plots were 6.1 m long, with 0.6 m between hills, and 2.5 m alleys at each end of the plot. The experiments were conducted using horticultural practices recommended to the growers by the North Carolina Extension Service (3). Soil type at Clinton was an Orangeburg loamy sand (Fine-loamy, kaolinitic, thermic Typic Kandiudults). Field preparation included the soil incorporation of 90-39-74 kg•ha^{-1} (N-P-K) of fertilizer, with an additional 34 kg•ha^{-1} of nitrogen applied at vine tip-over stage. We irrigated the plots when needed for a total of 30±10 mm of water per week. We applied a tank mix of 2.2 kg•ha^{-1} of naptalam and 4.4 kg•ha^{-1} of bensulide for weed control.

In 1987, we sowed the plots at two early planting dates (3 and 24 March) and at the recommended date for commercial growers in North Carolina (13 April). In 1988, we sowed the plots at two early planting dates (17 March and 4 April, respectively). In 1987, we sowed 120 seeds per plot, to be thinned to 60 plants per plot. Nevertheless, none of the plots had full-stand. In 1988, we sowed 100 seeds per plot and thinned them to 80 seedlings at the two true-leaf stage.

In 1987, we used black polyethylene mulch (hereafter referred to as mulch) and compared its effect with cultivation on bare ground (hereafter referred to as none). We tested row covers made of clear slitted polyethylene on wire hoops (hereafter referred to as clear) or floating nonwoven polyester (hereafter referred to as polyester) against no row covers (hereafter referred to as open). In 1988, we trialed cucumber cultivars for early production using a combination of mulch and polyester row covers.

We harvested the plots eight times, twice per week, 1987 (19 May through 15 June) and six times, twice per week, 1988 (26 May through 16 June) for fruit yield measurements. We counted and weighed cull and marketable fruit for each plot. Yield was measured as total, marketable, and cull weight (Mg•ha^{-1}) and number (thousands•ha^{-1}) of fruit by summing plot yields over harvests.

We monitored air and soil temperatures in the experimental fields with copper-constantan thermocouples attached to a micrologger and multiplexer. Air temperature sensors were placed in wooden radiation shields approximately five cm above the bed surface. The soil temperature sensors were buried ten cm deep in the soil in the center of the plot. The micrologger recorded hourly averages of the mean, maximum, and minimum of five-minute temperature readings.

We conducted statistical analyses using the MEANS, CORR, and GLM procedures of SAS-STAT Statistical Software Package (SAS Institute, Cary, North Carolina). The experiments were randomized complete block designs with four replications and a split-split-plot treatment arrangement. Factors were: planting date as whole plot, crop (pickling vs. slicing type) as sub-plot, mulch and row cover (1987) or cultivar (1988) as sub-sub-plot. In 1987, plant stand was calculated as percent of the best stand, which was obtained for both crops using black polyethylene mulch and clear polyethylene row covers at the latest planting date (13 April). In 1988, plant stand was uniform and plants were thinned to 80 per plot.

Results

In 1987, the daily air and soil temperature were similar in plots without mulch (Figure 1) and in plots with mulch (Figure 2). Plots with hoop or floating row covers had higher air temperatures than plots without row cover. At the first planting date (2 March), the average daily air and soil temperatures were 7 to 12°C. In the later two planting dates, the temperatures were consistently above 10 and 15°C, respectively.

The highest plant stand per plot was recorded at the latest (commercial) planting date in plots with mulch and clear row cover (Table 1). The mean plant stand for this treatment combination was 40, thus we considered this value as 100% stand in order to standardize proportionally the counts from the other treatments. In general, we recorded higher plant stands in plots with row covers, with the exception of plots sown on 2 March and protected with clear row covers. We did not find consistent differences in plant stand between chilling resistant and chilling susceptible germplasm. Nevertheless, the lack of full stand counts on plots sown at the commercial planting date (13 April) may indicate that factors other than chilling resistance, mulch, and row cover may have influenced plant stand in our experiment, resulting in reduced seed germination and seed vigor due to wet soil after spring rainfalls.

In 1987, total yield was increased by the use of chilling resistant germplasm, with a 46% average gain over the mean yield of chilling susceptible germplasm

(Table 1). The percent early yield at the third harvest was also higher (140%) for the chilling resistant germplasm. Overall, the use of mulch and row cover increased yield, and yields of protected plots were higher at the earlier planting dates. The higher yields at the two planting dates in March were not significantly different, but they were more than one LSD interval apart from the highest yields of plots sown at the commercial planting date of mid-April. There were no significant differences in yield for different row cover types within mulch treatment at the later planting date, but some treatments with row cover at the earlier planting dates had significantly higher yields.

In 1987, we confirmed the usefulness of mulch and row covers in increasing yield, particularly when chilling resistant and chilling susceptible cucumbers are planted earlier than typically done by commercial growers in North Carolina. Polyester row covers had a significant advantage over clear row covers only at the 2 March planting date. Total yield in plots covered with polyester was 128% higher for the chilling resistant cultivar, and 191% higher for the susceptible one. In addition, polyester row covers were easier to place on the plots and could be used for more than one production cycle. Thus, for 1988, we chose to use a combination of black polyethylene mulch and floating polyester row covers for our trial of several chilling resistant and chilling susceptible cultivars of pickling and slicing cucumbers.

In 1988, Gy 14A, 'Calypso', 'Castlepik', 'Raleigh', and M 29 for the pickling type, and 'Supergreen', 'Dasher II', 'Centurion', and 'Sprint 440S' for the slicing type, all planted at the earlier planting date, had the highest yield in the trial (Table 2). The earlier planting date greatly increased yield of the best cultivars in the trial. The top performing cultivars of the pickling crop had a 53% average gain in total yield over the same cultivars planted later. The highest-yielding of the slicing type had a 22% average gain, with the exception of 'Centurion' (gain = 3%).

The highest-yielding cultivars, planted on 17 March, had also the highest early yield at the third harvest (Table 2). The non-marketable yield (cull fruit weight) was not significantly affected by the planting date for any of the cultivars tested.

Genetic resistance to chilling seemed to favor the establishment of a better plant stand in 1987. However, it did not contribute to stand establishment or to yield improvement in 1988 since we obtained 100% plant stand in every plot. Under this conditions, cultivars that were described as chilling susceptible produced similar yields to chilling resistant cultivars within the same LSD intervals. Thus, we were not able to confirm with certainty whether chilling resistance had an advantage over susceptibility for the anticipated production of spring-planted cucumbers.

We found that the use of mulch and polyester row covers would allow early production of cucumbers (pickling and slicing types) in North Carolina. The field could be planted as early as mid-March, thus anticipating traditional cultivation of one month. Furthermore, the use of mulch and row covers in our experiment increased yield of commercial cultivars dramatically, when compared to the yield of the same cultivars planted at the commercial planting date for this crop in our state.

Further investigation is needed to determine the economics of protected culture of cucumbers for growers in North Carolina. The average market value for early production should be determined and the profit gain compared with the higher costs due to the use of polyethylene and polyester (cost of purchase, management, and disposal). Finally, a higher level of genetic chilling resistance would be useful for crops planted in early spring.

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Table 1. Yeild of chilling resistant and chilling susceptible cucumber cultivars in early spring using row covers and plastic mulch at Clinton, North Carolina 1987.

					Yield per hectare					
			% Stand [2]		Total Mg [3]		% Cull [4]		% Early [5]	
Planting date	Soil mulch [6]	Row cover [7]	Res [8]	Sus [9]	Res [8]	Sus [9]	Res [8]	Sus [9]	Res [8]	Sus [9]
2 March	Mulch	Clear	13	5	14.7	5.4	15	8	49	31
		Polyester	55	30	33.6	15.7	20	9	64	26
		Open	53	3	15.8	1.1	13	20	49	10
	None	Clear	70	8	34.3	3.8	20	14	71	12
		Polyester	23	20	12.6	2.5	8	8	32	9
		Open	15	0	7.8	-	13	-	26	-
23 March	Mulch	Clear	88	90	37.7	28.1	34	19	71	49
		Polyester	90	95	31.4	28.6	33	20	72	40
		Open	40	15	13.6	15.8	14	23	43	28
	None	Clear	40	70	21.1	17.4	14	16	59	26
		Polyester	28	65	3.5	6	18	12	16	14
		Open	10	5	1.9	0.2	9	11	4	0
13 April	Mulch	Clear	100	100	26.9	27.3	44	34	34	5
		Polyester	93	90	29.1	27.9	35	28	30	3
		Open	88	65	23.6	18.7	24	24	13	1
	None	Clear	95	93	26.5	18.9	31	33	10	1
		Polyester	73	45	18.5	10	25	12	3	0
		Open	45	38	11.2	7.7	23	29	0	0
	LSD (5%)		*11*	*12*	*7.7*	*7.1*	*11*	*10*	*11*	*13*
	Mean		*57*	*47*	*20.2*	*13.8*	*22*	*19*	*36*	*15*

1 Data are plot yields summed over eight harvests and averaged over replications. The experiment had a RCBD with a split-split-plot treatment structure: planting date was the whole-plot factor, chilling resistance level was the split-plot factor, and soil mulch and row cover were the split-split-plot factors.
2 Plant stand standardized by the best treatment stand (Black polyethylene mulch and clear polyethylene cover).
3 Total yield after eight harvests.
4 (Non-marketable yield × 100) / Total yield.
5 Percent of total yield after the first three of eight harvests.
6 Black polyethylene (mulch) vs. None.
7 Clear slitted polyethylene on wire hoops (clear) vs. Floating non-woven polyester (polyester) vs. Open.
8 'Wisconsin SMR 18', resistant to chilling at T<5°C.
9 'Poinsett 76', susceptible to chilling at T<5°C.

Table 2. Yield of chilling resistant and chilling susceptible cucumber cultivars planted under floating polyester covers with plastic mulch on 17 Mar. and 04 Apr. at Clinton, North Carolina 1988.

Planting date	Cultivar name	Chilling resistance [4]	Yield per hectare: Total Wt. (Mg)	Total No. (Th)	Marketable Wt. (Mg)	Marketable No. (Th)	Cull [2] (%)	Early [3] (%)
Pickling cucumbers								
17 March	Gy 14 A	S	43.0	808	33.3	624	22	65
	Calypso	S	40.3	715	33.6	595	16	64
	Castlepik	-	39.7	831	33.9	703	14	64
	Raleigh	-	38.8	758	32.2	625	17	57
	M 29	S	33.0	600	26.3	476	20	61
	Pixie	R	30.8	535	28.1	487	9	59
	M 28	S	30.4	536	22.8	404	25	66
	Wisconsin SMR 18	R	27.1	412	20.8	320	23	53
	M 21	R	24.9	468	20.6	384	17	53
	Sumter	S	24.8	383	21.6	335	13	41
	Wautoma	S	24.7	484	20.3	413	18	41
	Chipper	R	21.3	350	19.6	321	8	37
	H-19	R	16.2	294	14.8	266	9	17
	Albion	S	12.2	171	10.4	148	14	23
4 April	Castlepik	-	30.6	592	27.6	525	10	51
	Raleigh	-	29.8	633	26.0	550	13	58
	M 29	S	25.0	433	22.4	385	10	46
	Pixie	R	24.6	350	23.0	320	7	48
	Calypso	S	24.2	471	21.1	408	13	50
	Wisconsin SMR 18	R	22.7	366	18.5	295	18	45
	M 28	S	21.9	421	17.8	337	19	45
	Gy 14A	S	20.9	429	17.9	371	14	49
	Sumter	S	20.2	378	17.7	338	12	36
	M 21	R	18.2	340	16.9	308	7	28
	Chipper	R	15.8	267	14.4	242	9	29
	Wautoma	S	12.1	261	10.7	235	11	11
	H-19	R	11.6	259	10.9	242	6	5
	Albion	S	10.8	146	9.2	122	15	12
	LSD (5%)		*9.2*	*163*	*7.1*	*129*	*7*	*15*
Slicing cucumbers								
17 March	Supergreen	-	55.9	250	47.6	197	15	57
	Dasher II	S	52.2	217	46.9	191	10	59
	Centurion	S	51.4	219	41.7	164	19	51
	Sprint 440S	S	50.1	197	42.8	160	15	51
	Early Triumph	-	38.7	147	34.8	128	11	26
	Ashley	S	38.5	153	34.9	134	9	18
	Palomar	-	33.9	135	30.3	116	11	15
	Straight 8	S	33.5	133	25.4	89	28	45
	Pacer	-	30.0	127	27.1	111	9	26
	Mekty Green	-	29.8	62	20.1	41	33	12
	Marketmore 76	S	22.2	80	20.9	74	5	5
	Poinsett 76	S	18.3	71	17.9	69	2	17
	Tablegreen 65	S	11.5	43	10.1	36	12	4
	Lemon	-	4.3	44	4.2	44	2	3

[Continued on next page.]

Table 2 [continued].

4 April	Sprint 440S	S	48.4	199	37.7	143	12	65
	Supergreen	-	46.5	186	37.7	139	19	72
	Centurion	S	43.4	176	35.2	134	19	60
	Straight 8	S	41.2	156	31.7	108	24	57
	Dasher II	S	40.7	163	35.7	135	12	61
	Palomar	-	33.7	134	27.8	108	17	37
	Early Triumph	-	33.7	128	29.6	108	12	28
	Ashley	S	29.4	117	25.2	95	14	39
	Marketmore 76	S	26.5	107	22.4	86	15	18
	Pacer	-	26.3	110	22.9	92	13	28
	Poinsett 76	S	22.3	95	19.3	79	13	43
	Mekty Green	-	17.3	40	9.9	24	45	22
	Tablegreen 65	S	14.7	58	12.0	45	18	2
	Lemon	-	11.8	87	11.7	86	1	12
	LSD (5%)		*6.7*	*29*	*6.1*	*25*	*6*	*15*

1 Data are plot yields summed over six harvests and averaged over replications. The experiment had a RCBD with a split-split-plot treatment structure: planting date was the whole-plot factor, crop was the split-plot factor, and cultivar was the split-split-plot factor.
2 (Non-marketable yield × 100) / Total yield.
3 Percent of total yield after the first three of six harvests.
4 R = Resistant to chilling at T<5°C; S = Susceptible to chilling at T<5°C.

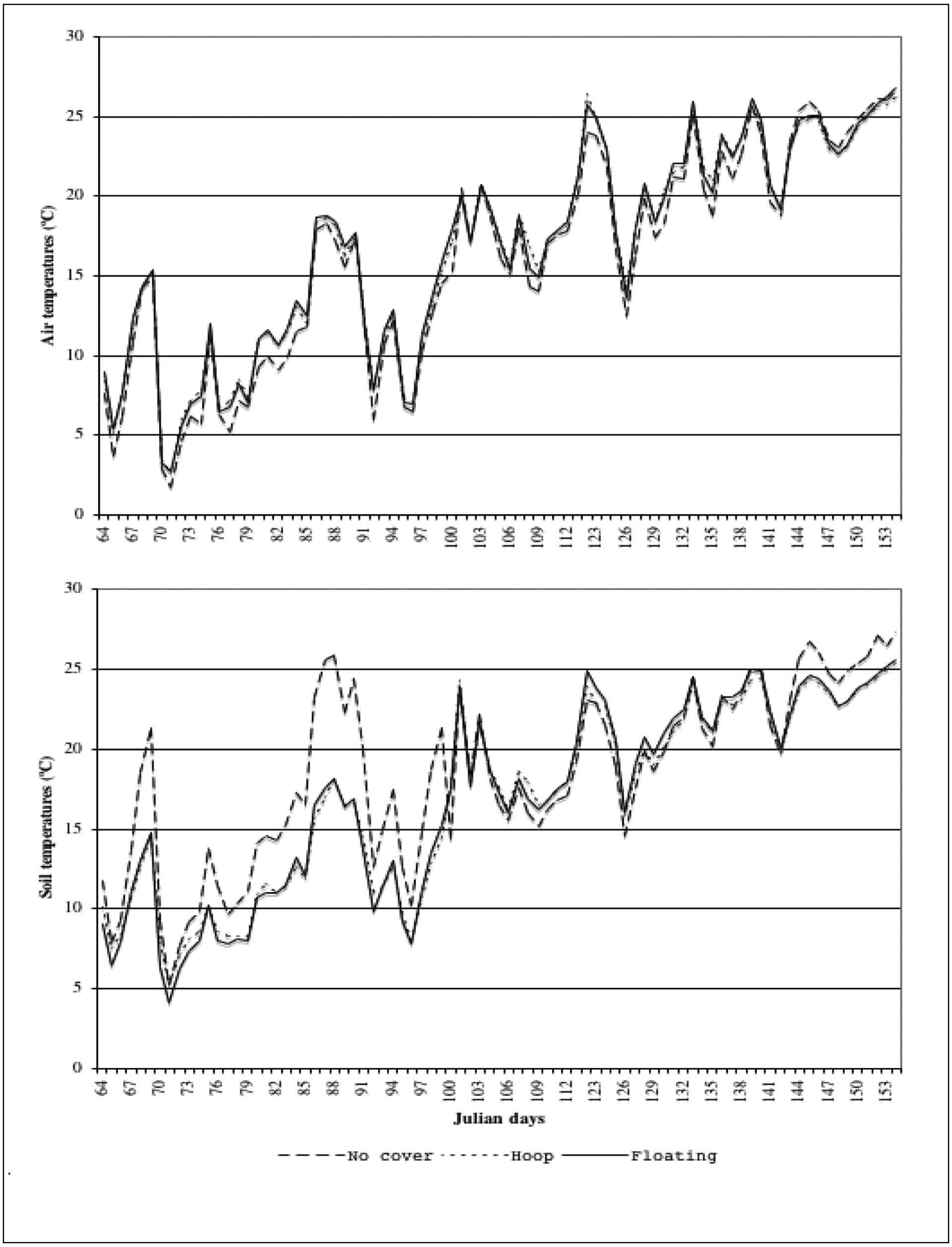

Figure 1. Average air and soil temperature of plors without mulch under different row covers during the trials of 14 pickling and 14 silcing cucumbers for early production at Clinton, North Carolina, 1987. The planning dates of 2 March, 23 March, and 13 April correspond to days 64, 85, and 106 of the Julian calender.

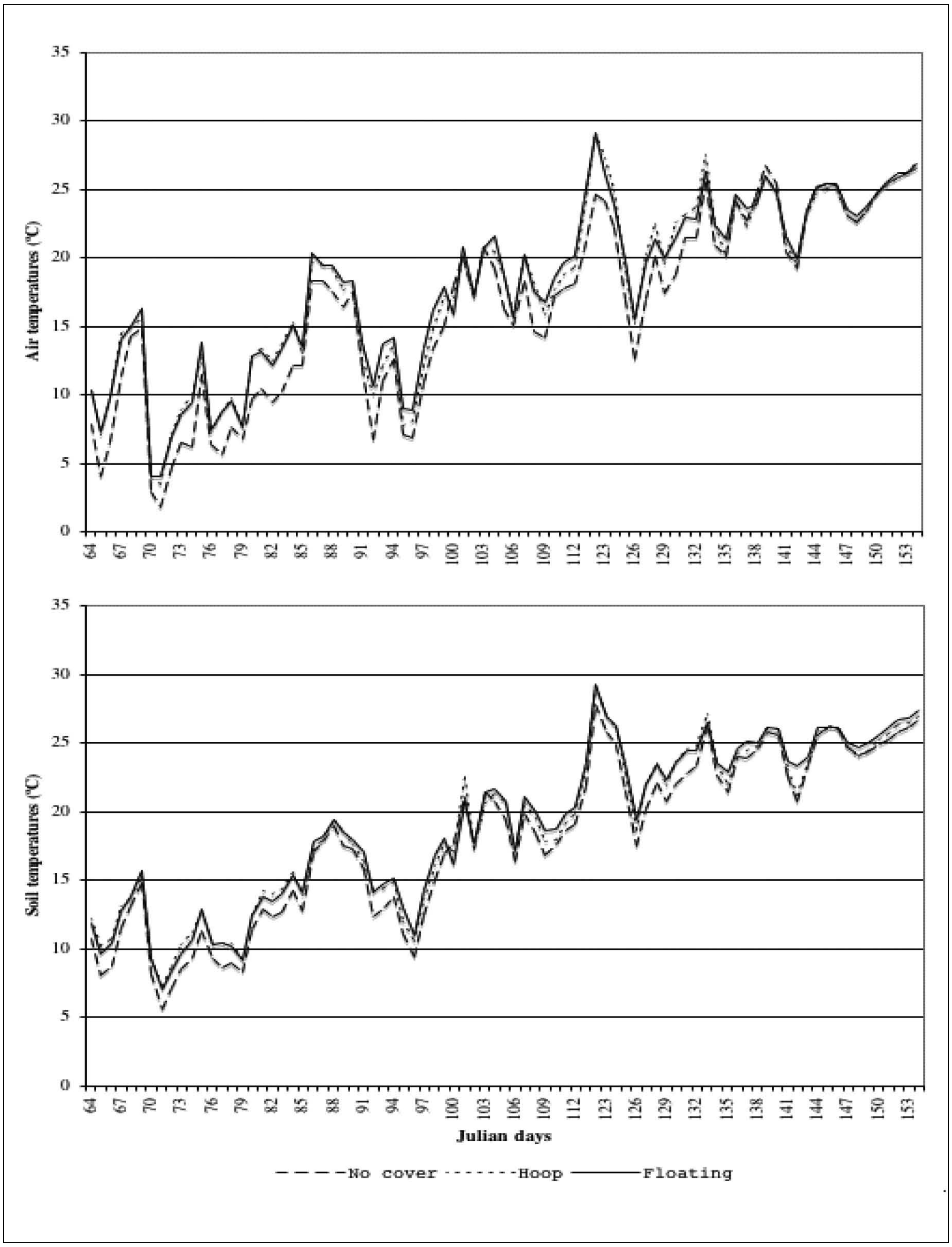

Figure 2. Average air and soil temperature of plots with black polyethylene mulch under different row covers during the trials of 14 pickling and 14 slicing cucumbers for early production at Clinton, North Carolina, 1987. The planting dates of 2 March, 23 March, and 13 April correspond to days 64m 85, and 106 of the Julian calendar.