Annual Strawberry Hill Cultural System in Southeastern North Carolina

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Abstract. The potential for annual cropping of strawberries in hill culture on black plastic mulch was investigated using 2 experimental plantings in southeastern North Carolina from 1982–1984. In 1982–1983, a plant density trial was conducted with freshly dug plants set in mid-October at a plant spacing of 33 cm between the double rows and spacings of 15, 20, 25, and 30 cm between plants in the row. Except with ‘Titan’, the highest strawberry yields in the spring of 1983 were obtained at the 15 cm in-row spacing. Fruit size of all cultivars was somewhat reduced at closer spacings. In a 1983–1984 trial, summer planting of dormant plants was compared to that of freshly dug plants set in mid-October. In December of 1983, record cold temperatures (~14°C) severely damaged leaves, crown tissues, and blossom primordia of dormant plants, whereas freshly dug plants had less freeze injury and higher fruit yields the following spring.

North Carolina strawberries are commonly grown in spring-planted, matted rows spaced 1.0 m to 1.2 m apart with in-row mother plant spacing from 45 cm to 61 cm to give an initial plant population ranging from 11,960 to 20,500 plants-ha-1 (7). This system depends on adequate runner production during the first growing season to achieve the recommended density of 4–6 plants/0.09 m² for cropping the following spring. Obtaining satisfactory matted row plant stands in the coastal plain of North Carolina is difficult in some years, because of excessively warm summer temperatures that check vegetative development, problems with periodic outbreaks of anthracnose (Colletotrichum fragariae Brooks), and a lack of commercial cultivars with tolerance to this fungus.

Variable matted row plant stands and high susceptibility of runner plants to anthracnose in this region has stimulated interest in fall planted annual hill cultural systems (2, 4, 5, 6, 8, 10). Experience with polyethylene mulch beds and fall planting in North Carolina has been limited. A 1970–1971 grower trial in Columbus County, NC, recorded a yield of 22,200 kg-ha-1 with this system, but a 40-ha commercial planting made in the fall of 1971 with freshly dug ‘Earlibelle’ produced disappointing yields, possibly because of cold injury and blossom losses to late spring freezes in 1972 (unpublished report).

Early spring blossom losses to freeze injury are no longer viewed as a major constraint to strawberry production on polyethylene mulch because of current widespread use of overhead sprinkler irrigation for frost/freeze protection (7). However, winter cold injury to polyethylene mulch bed plants may be a more serious concern in southeastern North Carolina where temperatures below ~6°C, considered critical for blossom primordia injury (3), occur during almost every winter season.

Numerous experimental investigations are needed before annual hill system cultural recommendations can be made for southeastern North Carolina. The present work focuses on the effects of plant density with 4 regionally popular cultivars on first year yield and fruit size, and a comparison of yields of dormant vs. freshly dug plants.

Field experiments were conducted in 1982–1983 (Expt. 1) and 1983–1984 (Expt. 2) in southeastern North Carolina at the Clinton and Castle Hayne Horticultural Crops Research Stations, respectively, on a Norfolk sandy loam with 0.5% organic matter content (Expt. 1) and on a Lynchburg loamy fine sand with 1.0% organic content (Expt. 2).

The bed preparation and planting practices in both tests were as follows. Broadcast fertilizer (10N–4.4P–8.3K) at 560 kg-ha⁻¹ was applied prior to disking in mid-September. Rows 1.4 m apart were rough bedded 30 cm high and 61 cm wide with disk hilling, and sulfur coated urea (36N–OP–OK) was applied in a band 10 cm deep in bed centers at the rate of 155 kg·ha⁻¹. The soil was irrigated and pressed to a 20-cm high bed slightly peaked at the center, 50 cm wide on top and 66 cm at the base. Fumigant (98% methyl bromide–2% chloropicrin) was injected in beds at broadcast rate of 393 kg·ha⁻¹ and 10-cm deep by 2 chisels spaced 30 cm apart beneath a multi-purpose single row fumigation and plastic applicator unit. Em-bossed black polyethylene 1.2 m wide was applied as a full-bed mulch cover at fumigation and plants with roots pruned to 15 cm in length were hand transplanted through the plastic mulch, about one week after fumigation, in holes cut by a spacing wheel. Leaves of freshly harvested plants were left intact.

Irrigation was applied immediately after planting and then run continuously during the hours 0100–1700 hr at 0.3 cm/hr for 5 days following transplanting of freshly dug plants. Dormant plants did not require a watering schedule as intensive as for freshly dug plants. Spring frost protection was facilitated with overhead irrigation, and the spray program used to control insects and diseases was that recommended for commercial production in North Carolina.

Fully red fruit were harvested twice weekly, from 14 Apr. 1983 to 6 June 1983 (Expt. 1), and 13 Apr. 1984 to 29 May 1984 (Expt. 2). Marketable fruit from each plot were counted and weighed; fruit irregular in shape or decayed were classified as culls. Analyses of variance were calculated for marketable yield, fruit size, and percentage of cull fruit. Regression analysis was used to evaluate spacing effects in Expt. 1; planned comparisons were used to gain insight into the nature of strawberry cultivar responses to planting system in Expt. 2.

Expt. 1. Field-grown, North Carolina certified plants of ‘Apollo’, ‘Earlibelle’, ‘Earliglow’, and ‘Titan’ were harvested on 8 Oct. 1982 and held in cold storage (2.2°C) until planting 2 days later in Clinton. The plant spacing in the row was 15, 20, 25, and 30 cm with 33.0 cm spacing between off-set double rows. The experimental design was a split plot of 5 replicates, with spacing as the main plot and cultivars as subplots. Each subplot was 3 m in length.

Expt. 2. Two planting systems were compared—summer planting of dormant plants on 25 Aug. 1983 and fall planting of freshly dug plants on 17 Oct. 1983. Four basic differences in the handling of summer and fall plantings in Expt. 2 from practices in California (4) were: a) black instead of clear polyethylene mulch was used; b) the summer system had the mulch applied at planting vs. delayed mulching in January or February, depending on the area in California; c) none of the foliage on freshly dug plants was removed prior to transplanting; and d) the summer planting did not have its foliage pruned in winter. Dormant stored ‘Douglas’, ‘Pajaro’, and ‘Tufts’ were from Lassen Canyon nursery, Redding, Calif., and dormant ‘Apollo’, ‘Atlas’, ‘Earlibelle’, and ‘Earligrow’ were from Lewis Strawberry Nursery, Rocky Point, N.C. Plants of the same cultivars were freshly dug 17 Oct. 1983 from Lewis Nursery and planted the same day. Plant spacing in the row was 30 cm for both dormant and freshly dug plants; spacing between off-set double rows was 35 cm. The experimental design was split plot with 6 replicates with plant type (dormant vs. fresh)
Table 1. The effect of plant density on marketable strawberry yield, fruit size, and percentage of culls.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>In row spacing (cm)</th>
<th>Marketable fruit yield (MT-ha^-1)</th>
<th>Mean fruit size (g/fruit)</th>
<th>Percent cull (as % of total fruit number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo</td>
<td></td>
<td>33.4</td>
<td>9.5</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>30.3</td>
<td>10.2</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>26.3</td>
<td>10.8</td>
<td>6.9</td>
</tr>
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<td></td>
<td>30</td>
<td>21.6</td>
<td>11.1</td>
<td>7.1</td>
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<tr>
<td>Linear trend</td>
<td></td>
<td>*</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>Earlibelle</td>
<td></td>
<td>26.9</td>
<td>9.6</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>22.6</td>
<td>9.4</td>
<td>9.5</td>
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<tr>
<td></td>
<td>25</td>
<td>20.9</td>
<td>11.4</td>
<td>7.3</td>
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<td></td>
<td>30</td>
<td>14.7</td>
<td>10.9</td>
<td>8.6</td>
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<tr>
<td>Linear trend</td>
<td></td>
<td>***</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Earliglow</td>
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<td>17.9</td>
<td>10.0</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>15.2</td>
<td>10.1</td>
<td>10.2</td>
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<td></td>
<td>25</td>
<td>13.9</td>
<td>11.1</td>
<td>8.4</td>
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<td></td>
<td>30</td>
<td>12.1</td>
<td>11.1</td>
<td>8.5</td>
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<tr>
<td>Linear trend</td>
<td></td>
<td>***</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Titan</td>
<td></td>
<td>22.8</td>
<td>16.2</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>23.8</td>
<td>16.5</td>
<td>6.3</td>
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<td></td>
<td>30</td>
<td>18.7</td>
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<td>5.9</td>
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<tr>
<td>Linear trend</td>
<td></td>
<td>NS</td>
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<td>NS</td>
</tr>
</tbody>
</table>

* **, ***; ns; linear effect significant at 5%, 1% or 0.1% or not significant, respectively.  
Extrapolated yield means from 1.4 m x 3.0 m plots.  
The quadratic was nonsignificant.

Table 2. Influence of cultivar and cultural system on marketable strawberry yield, fruit size, and percentage of culls. Treatments are 7 cultivars and 2 planting systems.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Marketable fruit yield (MT-ha^-1)</th>
<th>Fruit size (g/fruit)</th>
<th>Percent cull (as % of total fruit number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant system</td>
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<tr>
<td>Plant system x cultivar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant density systems</td>
<td>sum of squares (Ta-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 'Apollo', 'Atlas', 'Douglas', 'Earlibelle', 'Earliglow', 'Pajaro', and 'Tufts' were injured severely relative to damage suffered by freshly dug plants of the same cultivars. This result probably is related to the vigorous growth of summer-set dormant plants in the fall and early winter prior to the freeze. Freshly dug plants did not make significant vegetative growth during this period and appeared to acclimate better than dormant plants.

The original analysis of variance revealed several significant main effects for planting system (dormant vs. freshly harvested) and cultivar as well as significant interactions for marketable yield and fruit size (Table 2). Means for the effects of planting system and cultivar are not presented, since the interaction makes them meaningless. Table 3 shows the relevant effects of the experiment, and gives the statistical information germane to the comparisons planned to investigate whether the 6 strawberry cultivars of greatest interest ('Apollo', 'Atlas', 'Douglas', 'Earlibelle', 'Earligrow', and 'Pajaro') respond differently to planting systems.

In 1984, freshly harvested plants of 'Apollo', 'Douglas', and 'Earlibelle' had significantly higher marketable yields than dormant plants. Although 'Atlas' had a yield of 15.9 MT-ha^-1 for dormant vs. 13.9 MT-ha^-1 for freshly dug, it was not statistically different. 'Earligrow' and 'Pajaro' also were similar (Table 3). Fruit size of 'Apollo', 'Earlibelle', and 'Pajaro' was significantly increased in freshly dug plants. Fall planted current-season nursery plants were generally 10-14 days earlier in ripening than summer planted dormant stored plants.

Previously, fall planting systems with freshly dug plants have been satisfactory only in areas where mild winter temperatures prevail (2, 6, 10). Despite record cold temperatures in the early winter of 1983, spring 1984 yields from freshly harvested plants of 'Apollo', 'Atlas', 'Douglas', and 'Earlibelle' were comparable to that obtained in well-managed matted row commercial plantings in southeastern North Carolina. Summer plantings made from plants dug in winter and then held in cold storage for planting in late August generally were not found to be as reliable as fall planting of freshly dug plants. 'Atlas' was well-adapted to either planting system, but dormant plants were delayed in ripening by about 10 days relative to freshly dug plants of this cultivar.

Table 3. The effect of cultivar and planting system on strawberry marketable yield and fruit size.

<table>
<thead>
<tr>
<th>Planting system</th>
<th>'Apollo'</th>
<th>'Atlas'</th>
<th>'Douglas'</th>
<th>'Earlibelle'</th>
<th>'Earligrow'</th>
<th>'Pajaro'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.1 a</td>
<td>13.9 a</td>
<td>12.8 a</td>
<td>12.6 a</td>
<td>8.6 a</td>
<td>8.1 a</td>
</tr>
<tr>
<td>Fresh dug</td>
<td>7.2 b</td>
<td>15.9 a</td>
<td>9.5 b</td>
<td>9.1 b</td>
<td>6.1 a</td>
<td>8.1 a</td>
</tr>
<tr>
<td>Dormant</td>
<td>11.4 a</td>
<td>16.4 a</td>
<td>13.3 a</td>
<td>11.1 a</td>
<td>8.9 a</td>
<td>16.0 a</td>
</tr>
<tr>
<td>Fresh dug</td>
<td>10.7 a</td>
<td>13.7 b</td>
<td>12.5 a</td>
<td>10.0 b</td>
<td>8.4 a</td>
<td>13.0 b</td>
</tr>
</tbody>
</table>

* Mean separation within cultivar by F test at 1%.

Literature Cited

Comparison of Drip and Furrow Irrigation for Muskmelon Production

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Additional index words: trickle irrigation, water use efficiency, Cucumis melo

Abstract. Drip and furrow irrigation of muskmelon (Cucumis melo L. ‘Perlita’) were compared in 1983 in Weslaco, Texas. Drip irrigation at 40% or 20% available soil water depletion (SWD) in the surface 30 cm of soil required 25% and 42%, respectively, of the irrigation water volume required by furrow irrigation at 40% SWD. There was a trend toward earliness and increased total and marketable yields with drip irrigation. Neither fruit size distribution nor cull percentage was affected by irrigation method. In 1984, drip irrigation at 20%, 40%, or 60% SWD showed increased muskmelon yield with increased water application. Drip irrigation regime did not influence earliness, fruit size distribution, or soluble solids content. Highest water use efficiency, 181 kg marketable fruit·ha⁻¹·mm⁻¹ total water (irrigation + rainfall), was recorded in the 40% SWD treatment.

The subtropical Lower Rio Grande Valley (LRGV), the main vegetable production area of Texas, is facing a severe agricultural water shortage (12). Muskmelon is a major crop in the LRGV, covering nearly 5000 ha. Four to 6 furrow irrigations commonly are applied, with seasonal application frequently exceeding 600 mm of water. In addition to inefficient water use, furrow irrigation of saline soils can reduce aeration, slow growth, and restrict root development. Furthermore, furrow irrigation interrupts routine field operations and therefore is often scheduled on the basis of convenience rather than need.

Drip irrigation is an alternative method that potentially could improve water use efficiency while minimizing the cultural problems associated with furrow irrigation. Although drip irrigation has been reported to increase yield and water use efficiency (1, 6, 7), other studies have shown either equivalent yields (3, 4, 9) or equivalent water requirements (2, 3, 11) when comparing drip and furrow irrigation. This diversity of results arises in part from the wide variation in drip irrigation regimes tested. Irrigation frequency, placement, and water volume influence crop response. Rainfall patterns, soil characteristics, and water quality also influence the comparison of irrigation methods. This study was undertaken to determine relative muskmelon yield response and water use efficiency of furrow irrigation and various drip irrigation regimes.

All work was performed on the Texas A&M Research Center, Weslaco, Texas. The studies were conducted on a Hidalgo sandy clay loam of pH 8.0 with a bulk density of 1.35 and 14.3% (v/v) available moisture. Field capacity was determined by flooding the area inside 0.45-m diameter rings in the field. The rings were covered with black plastic to minimize evaporation. Soil samples for gravimetric moisture determinations on intact soil cores. Comparison of furrow and drip irrigation, 1983. Two tests, comparing conventional furrow irrigation with different drip irrigation regimes, were conducted in Spring 1983. Soil was worked into raised beds on 2 m centers. Nitrogen and P at 20 and 29 kg·ha⁻¹, respectively, were placed 10 cm deep in 2 bands 15 cm from the bed center. Single 0.5 mm thickness BiWall (RIS Irrigation Systems, El Cajon, Calif.) drip irrigation lines with a 30-cm emitter spacing were buried 15 cm deep in the center of each drip-irrigated bed. ‘Perlita’ muskmelon was seeded in single rows per bed on 28 Feb. Plants were thinned to a final in-row spacing of 30 cm.

Gravimetric soil moisture determinations were made 3 times a week on 30-cm soil cores taken 15 cm from the bed center. Furrow irrigations were delivered in both tests when available soil water depletion (SWD) reached 40%. Drip irrigation was applied at either 40% SWD (Test 1) or 20% SWD (Test 2). Furrow- and drip-irrigated plots were separated by 2 border rows (4 m) to minimize water movement between treatments. A randomized complete block design with 4 replications was used. Individual plots were 24 m long. All plots were furrow-irrigated on 25 Mar., when the plants were at the 4 to 6 true-leaf stage. Differential irrigation treatments began thereafter. Each furrow irrigation delivered 5 to 8 cm of water. In both tests, drip irrigation was applied for 5 hr at 4 liters-hr⁻¹·m⁻¹, delivering about 1 cm of water.

Sixty-seven kg N·ha⁻¹ were banded 8 cm deep into the bed shoulders of all furrow-irrigated plots on 14 Apr. and watered in on 21 Apr. The same rate of N was injected through the drip lines in drip-irrigated plots in both tests on 22 Apr. Standard commercial production practices were followed. Harvests began 31 May and continued until 22 June. Fruit were picked at full-slip and separated into size categories corresponding to those used in the commercial trade: 27, 23, 18, 15, or 12 fruit/18-kg carton. Fruit were cull percentage was affected by irrigation method. In 1984, drip irrigation at 20%, 40%, or 60% SWD showed increased muskmelon yield with increased water application. Drip irrigation regime did not influence earliness, fruit size distribution, or soluble solids content. Highest water use efficiency, 181 kg marketable fruit·ha⁻¹·mm⁻¹ total water (irrigation + rainfall), was recorded in the 40% SWD treatment.

Comparison of drip irrigation regimes, 1984. Raised soil beds on 2 m centers were prepared, and N and P at 27 and 40 kg·ha⁻¹, respectively, were banded as in 1983. A single BiWall drip irrigation line was buried 15 cm from the bed center. Furrow irrigations were delivered in both tests when available soil water depletion (SWD) reached 40%. Drip irrigation was applied at either 40% SWD (Test 1) or 20% SWD (Test 2). Furrow- and drip-irrigated plots were separated by 2 border rows (4 m) to minimize water movement between treatments. A randomized complete block design with 4 replications was used. Individual plots were 24 m long. All plots were furrow-irrigated on 25 Mar., when the plants were at the 4 to 6 true-leaf stage. Differential irrigation treatments began thereafter. Each furrow irrigation delivered 5 to 8 cm of water. In both tests, drip irrigation was applied for 5 hr at 4 liters-hr⁻¹·m⁻¹, delivering about 1 cm of water.

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