ABSTRACT

Wilkinson, William Charles. Effects of Stand Loss, Planting Date, and Replanting Method on Yield and Quality of Flue-cured Tobacco. (Under the direction of Dr. Loren R. Fisher)

In 2002, early season infections of tomato spotted wilt (TSW) caused significant stand losses and more than a 6% overall crop loss in flue-cured tobacco in North Carolina. Research was conducted at one location in 2003 and two locations in 2004 to evaluate the effects of stand loss, planting date, and replanting method on flue-cured tobacco yield and quality. Stand loss treatments included a 10, 20, 30, and 40% stand loss, two and four weeks after transplanting. A TSW loss simulation consisting of a 10 %, 10 %, and 20 % stand loss at 3, 4, and 5 weeks after transplanting, respectively, was also included. Planting date treatments included planting at the normal transplanting date and 2, 3, 4, and 5 weeks after the normal transplanting date. To evaluate the effects of replanting method tobacco was also replanted at 2 an 4 weeks after normal on an existing row ridge, a re-bedded row ridge, and a tilled and re-bedded row ridge.

Due to excessive rainfall, stand loss and planting date had no effect on yield or quality in 2003. In 2004, the TSW stand loss simulation reduced yield at one location, but no other stand loss treatment differences were observed. Delaying transplanting by 5 weeks at one location and by 4 or 5 weeks at one location reduced yield, but did not affect quality. Replanting treatments reduced yields compared to the respective delayed transplanting date in 2003, but did not affect quality. Yield and quality were not consistently affected by replanting method in 2004 when compared to the respective delay in transplanting.

Because stand losses from TSW are gradual, by the time stand losses reach the levels that significantly reduced tobacco yield in this research, yield loss associated with the late planting date would prohibit replanting from being a viable management option under conditions at these tests.

EFFECTS OF STAND LOSS, PLANTING DATE, AND REPLANTING METHOD ON YIELD AND QUALITY OF FLUE-CURED TOBACCO

By

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Biography

William Charles Wilkinson, son of Tom Wilkinson and Cynthia Blackburn, is a native of Cooleemee, North Carolina. At the age of 13 he moved to Hickory, North Carolina, and graduated from St. Stephens High School in 1998. After high school he attended North Carolina State University, and received a Bachelor of Science degree in Agronomy, with a minor in Agricultural Business Management in 2002. In January 2003 he was admitted to graduate school at North Carolina State University, and began work on a Master of Science in crop science, under the direction of Dr. Loren Fisher.

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Lastly the deepest appreciation is expressed to the author's parents who fully supported his decisions that led to this degree. Without this support, none of his accomplishments would have been possible.

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Introduction

Tobacco is very important to the economy of North Carolina and remains the largest cash crop produced in the state. In 2003, tobacco accounted for more than 8% (600 million dollars) of the total agricultural receipts in North Carolina, and more than 20% of crop receipts. Tobacco also comprised more than 27% (520 million dollars) of North Carolina's total agricultural export income (4).

Tomato spotted wilt (TSW) is a disease that affects many different species of crop plants, including tobacco. It was first observed in tobacco in North Carolina in 1989. From 1989 through 2001 it was present in low levels in tobacco, never causing more than a 1% total crop loss. However, during the 2002 season, TSW resulted in an estimated 6% loss in yield across North Carolina, mainly affecting tobacco in the Coastal Plain region (14). Other tobacco producing states in the southeast such as Georgia and Florida have been faced with the disease since the early 1980's, and regularly have stand losses of up to 40% (2).The disease is vectored from an infected plant to a healthy plant by thrips.

The two primary carriers of Tomato spotted wilt virus (TSWV) on tobacco in the U.S. are the western flower thrips (*Frankliniella occidentalis*) and the tobacco thrips (*Frankliniella fusca*). In order for thrips to vector the virus several events must occur. First, 1- to 2- day-old thrips must feed on infected tissue and acquire the virus in its digestive system. Next, the virus must move from the thrips' gut to the salivary glands. Then the thrips must mature into an adult with wings and feed on another susceptible plant (14). Winter weeds such as annual smallflower buttercup, mousear chickweed, common chickweed, and spiny sowthistle, as well as perennials such as dandelion and Rugel's plantain, are the most common weed sources of TSWV (14). When winter annual and perennial weeds die, either from natural senescence or chemical control, thrips must move to other plants to feed, thereby spreading TSWV (14). In 2002, when the disease was most severe in North Carolina, thrips were thought to vector TSWV to tobacco plants within several days following transplanting, with visual symptoms and plant death occurring for several weeks following infection. It is believed that an extremely dry spring caused an early senescence of winter weeds that coincided with the normal transplanting date for tobacco (14). The result was movement of thrips from their winter hosts to other green vegetation, which at the time in 2002 was primarily newly transplanted tobacco. Most of the losses from TSW in 2002 were related to early-season infections with TSWV that result in early season stand losses that reduced yield. Transplant death associated with TSW was gradual in 2002. In most cases it took several weeks to reach a level where growers considered replanting. Tobacco growers had to decide if the stand loss was severe enough to justify replanting and determine if replanting several weeks after the optimum transplanting date would reduce yield more than the stand loss observed.

Tobacco is unique among most agronomic crops because the leaves, not the reproductive organs, are the economically important portion of the plant and therefore, has exceptional ability to compensate for early season stand losses. According to Papenfus and Quin, a relatively small plant population per unit area will produce close to the maximum yield where the growing season is long (12). According to the 2003 South Carolina Tobacco Grower's Guide an early season stand loss of up to 10% can be tolerated without any adverse effects on yield (5). Other work conducted by Peedin in

1997 has shown that flue-cured tobacco could withstand a 15% stand loss, which occurred within a week of transplanting, without any significant reduction in yield, and at a 50% stand can produce 80% of the crop's potential yield (Personal communication Gerald F. Peedin, North Carolina State University, Raleigh, N.C.).

Additional research has been conducted to evaluate the effect of planting dates on yield and quality. Hawks and Bennett found that yield decreased approximately 8% per week, from three weeks to five weeks past the normal transplanting date (8). However, another delayed planting test conducted in the late 1970's showed more variable results. Miner found that at three of five locations there was no yield difference between the normal planting date and a two or four week delay in transplanting (11). In the remaining two locations, one showed a yield decrease with a two or four week transplanting delay and the other showed a yield increase at both two and four weeks after the normal planting date. Research conducted in Canada, where the growing season is significantly shorter than in North Carolina, found that delaying planting by four weeks decreased yield from 8% to 36% (1).

Data from past research indicate that response to planting date is highly dependent upon the growing season. It has been observed that increases in temperature and photosynthetically active radiation (PAR) sometimes observed in late planted tobacco compared to tobacco planted at the normal timing have been shown to cause more rapid growth, hasten floral initiation, produce thinner leaves, and possibly hasten senescence and reduce yields (6, 15). Later planted tobacco is also at greater risk for leaf diseases such as *Alternaria*, weather damage, and damage from insects such as budworms and aphids (7, 9, and 10).

Stand loss and planting date can also affect chemical and physical quality of the cured leaf. For example, a reduced plant population will affect leaf size and shape by increasing the stem to lamina ratio, which is not desirable for cigarette manufacturing companies (16). In addition, increased nitrogen availability associated with stand loss can cause an undesirable decrease in the alkaloid to sugar ratio in the cured leaf (17). Miner found that a two-week delay in planting resulted in the highest cured leaf quality grades in one year, while a four-week delay resulted in the lowest quality grades (11). Additional work in Canada showed that quality remained unaffected until three or four weeks after optimum planting dates (1).

Previous research on stand loss has provided valuable information for growers, but has not been able to answer many of the questions growers have concerning losses from early season TSW infections. Research on the effects of stand loss on yield and quality was only conducted for losses in the first several days after transplanting whereas stand losses from TSW tend to occur gradually over many weeks. In addition, transplanting date studies were conducted for four weeks or less after the normal transplanting date. In many cases in 2002, North Carolina growers did not reach critical levels of stand loss until five or more weeks after the normal transplanting date. Most of the research was also conducted with varieties that are not currently planted in North Carolina. Current varieties yield higher and mature later than those used in previous studies and may have a greater ability to compensate for stand loss or a late planting date.

Methods and Materials

Planting Date and Replanting Method

Research was conducted in North Carolina at the Central Crops Research Station (CCRS) near Clayton in 2003 and 2004 and at the Oxford Tobacco Research Station (OTRS) near Oxford in 2004 to determine the effects of planting date and replanting method on the yield, quality, and chemical characteristics of flue-cured tobacco. Soil series were a fine-loamy, kaolonitic, thermic, Plinthic Kandiudult at Clayton in 2003 and 2004, and a fine, kaolinitic, thermic Typic Kanhapludult at Oxford in 2004.

The experimental design was a four rep randomized complete block with four-row plots 12.2 m in length. Row width was 1.20 m at Oxford and 1.14 m at Clayton. In-row spacing was 0.56 m at both locations for both years. Plant populations were 15,650 per hectare at Clayton and 14,820 per hectare and Oxford. Varieties used in the experiments were K326 at Clayton, both years, and NC 297 in 2004 at Oxford. Tobacco was produced using recommended practices for the particular station, except for treatments imposed (13).

Planting dates were the normal date for each research station and a 2, 3, 4, and 5 week delay in planting. Actual planting and replanting dates for all experiments are shown in Table 1. Replanting methods included: replanting directly onto the previously formed ridge, rebedding prior to replanting, and tilling and rebedding prior to replanting. Replanting treatments were imposed 2 and 4 weeks after normal transplanting (WANT). All of the beds in the replanting treatment plots were partially flattened to approximately one-half original height and fertilized on the normal planting date, in order to simulate actual grower conditions and examine any negative effects caused by fertilizer injury or placement.

Table 1. Transplanting dates for Clayton in 2003 and 2004 and Oxford in 2003.

Transplanting date	Clayton 2003	Clayton 2004	Oxford 2004
Normal	May 3	April 26	May 7
2 week delay	May 15	May 10	May 21
3 week delay	May 21	May 17	May 28
4 week delay	May 29	May 25	June 4
5 week delay	June 4	June 1	June 11

In 2004, plant heights were recorded every 7 days, and continued until all of the tobacco in each plot had been topped. Flower counts, as a measure of maturity, were taken on the center two rows of the four row plots, starting at first open corolla and continuing on 3 to 4 day intervals, until all plants had flowered. Cured leaf yield and quality data were collected from the center two rows of the four row plot. The Tobacco Chemistry Laboratory in the Crop Science Department at North Carolina State University performed analysis for total alkaloids and reducing sugars of a 50g cured leaf sample, composited by weight over primings, from each plot.

All data were subjected to an analysis of variance (ANOVA) and treatment means were separated using a Fisher's F Protected Least Significant Difference test (LSD) at

$p \leq .0.05$. Because of significant location by year and location by treatment interactions, data are reported by location.

<u>Stand Loss</u>

Research was conducted at the Central Crops Research station (CCRS) near Clayton, NC in 2003 and 2004 and at the Oxford Tobacco Research station (OTRS) near Oxford, NC in 2004 to determine the effects of stand loss on the yield, quality, and chemical characteristics of flue-cured tobacco. Soil series were a fine-loamy, kaolonitic, thermic, Plinthic Kandiudult at Clayton in 2003 and 2004, and a fine, kaolinitic, thermic Typic Kanhapludult at Oxford in 2004.

Experimental design was a randomized complete block with four replications and two-row plots, 12.2 m in length. Row width was 1.20 m at Oxford and 1.14 m at Clayton. In-row spacing was 0.56 m at both locations for both years. Plant populations were 15,650 per hectare at Clayton and 14,820 per hectare and Oxford. Varieties were K326 at Clayton, both years, and NC 297 in 2004 at Oxford. Tobacco was produced using normal practices for each research station, except for treatments imposed (13).

After establishment of a 100% plant stand, 10, 20, 30, and 40% of the plants were removed at random, at two and four weeks after transplanting (WAT). Additional treatments included a Tomato Spotted Wilt virus (TSWV) loss simulation, where 10% of the plants were removed 3 WAT, 10% were removed 4 WAT, and 20%were removed 5 WAT, for a total stand loss of 40%. The TSWV loss simulation was based on observations of Dr. Tom Melton during the 2002 season in Duplin County. Stand losses were imposed on one row and the plants which were removed were selected through random number generation. Guard rows with a 100% stand were maintained on each side of the treated plot rows. Dates when each of the treatments were implemented as shown in Table 2.

Table 2. Dates and locations for stand loss treatments at in 2003 and 2004.

Date of treatment	Clayton 2003	Clayton 2004	Oxford 2004
Transplanting	May 3	April 26	May 7
2 week removal	May 15	May 10	May 21
3 week removal	May 21	May 17	May 28
4 week removal	May 29	May 25	June 4
5 week removal	June 4	June 1	June 11

Cured leaf yield and quality data were collected from the treated row of the two row plot. The Tobacco Chemistry Laboratory in the Crop Science Deptartment at North Carolina State University performed analysis for total alkaloids and reducing sugars of a 50g cured leaf sample, composited by weight over primings from each plot.

All data were subjected to an analysis of variance (ANOVA) and treatment means were separated using a Fisher's F protected least significant difference value (LSD). Because of significant location by year and location by treatment interactions, data are reported by location.

Results and Discussion

Data are reported by location because of significant location by treatment and location by year interactions.

Stand Loss

No differences in yield and value were observed with any of the stand loss treatments at the Clayton location in 2003 (Table 3). Compared to the control, average selling price was reduced with the 10 % and 30 % stand loss occurring four weeks after transplanting (WAT). In addition, grade index was reduced with the 20 % and 30 % stand loss 4 WAT. At the Clayton location in 2004, yield was reduced with the TSW simulated stand loss (10% , 10%, and 20% loss at 3, 4, and 5 WAT, respectively) (Table 4). No differences were observed in price, value, or grade index at Clayton in 2004. At Oxford in 2004, no differences were observed in yield, price, value, or grade index with any stand loss treatments (Table 5). Total sugars and alkaloids were not affected by any stand loss treatment at any location (Tables 3, 4, 5).

Leaves are the economically significant portion of the tobacco plant, therefore tobacco has a greater ability to compensate for stand loss than other agronomic crops which are harvested for seed or lint. In 2003, excessive rainfall and cooler than normal temperatures (Table 9) resulted in very low yields at the Clayton location and resulted in no differences among stand loss treatments. In 2004, environmental conditions were more favorable for plant growth which maximized the ability of tobacco to compensate for missing plants. The only yield reduction in the experiments was observed with the TSW stand loss simulation at one of three locations. A 40 % stand loss over time, with

20 % of the plant stand removed 5 WAT, reduced yield more than removing 40 % of the plant stand 4 WAT. It is apparent, that, under the environmental conditions experienced at Clayton in 2004, removal of plants more than four weeks after transplanting reduced the ability of tobacco to compensate for missing plants. Results indicate that yield response to stand loss is dependent on growing conditions throughout the season and timing of the stand loss. When timing and levels of stand loss are similar to those in this experiment, and when extremely poor growing conditions that significantly reduce overall yield, or highly favorable growing conditions occur, yield losses will be minimal.

Transplanting Date

Transplanting date had no effect on yield, price, or value at the Clayton location in 2003 (Table 6). Tobacco planted four and five weeks after the normal transplanting date did, however, have a higher grade index in 2003 at the Clayton location. In 2004 at Clayton, yield was only reduced by transplanting five weeks after the normal date (Table 7). Price and value were reduced by transplanting four and five weeks after the normal date. Grade index was not affected by transplanting date at Clayton in 2004. At Oxford in 2004, yield and value were reduced by transplanting four and five weeks after the normal date but price and grade index were not affected by any transplanting date treatment (Table 8).

At Clayton in 2003, total alkaloid levels were extremely low and is likely related to root damage associated with excessive rainfall. No transplanting date related treatment differences in total alkaloids or sugars were observed. In 2004, no differences in total alkaloids or sugars were observed at either location and sugar and alkaloid levels were within a normal range (Tables 7, 8)(16).

Results are similar to the stand loss studies. With the poor growing conditions experienced in 2003 (Table 9), transplanting date had little to no effect on yield, price, value, or quality. When environmental conditions were more favorable, especially early in the season, delaying transplanting by four or more weeks reduced yield and value but did not consistently reduce chemical or physical quality.

Replanting Method

Results from replanting method studies were highly variable. At Clayton in 2003, all simulated replanting treatments imposed four weeks after the normal transplanting date reduced yield and value compared to a four week delay in transplanting and compared to tobacco transplanted on the normal date. In addition, re-bedding or tilling and re-bedding prior to replanting, two weeks after the normal transplanting date, reduced yield compared to tobacco transplanted at the normal date, but not compared to a two week delay in transplanting. Replanting on the existing row ridge and a two week delay in transplanting did not affect yield compared to tobacco transplanted at the normal date. Replanting treatments did not consistently affect price or grade index at Clayton in 2003.

At Clayton in 2004, replanting two weeks after the normal transplanting date did not affect yield, price, value, or grade index when compared to a two week delay in transplanting or when compared to tobacco transplanted at the normal date. Four weeks after the normal transplanting date, no replanting treatment reduced yield, price, value, or quality compared to a four week delay in transplanting. However, replanting on the existing row ridge and re-bedding prior to replanting did reduce yield compared to tobacco transplanted at the normal date when other four week transplanting/replanting treatments did not.

At Oxford in 2004, replanting method did not affect yield, price, value, or grade index two and four weeks after the normal transplanting date when compared to their respective delayed transplanting treatment. All replanting treatments imposed four weeks after the normal transplanting date reduced yield and value when compared to tobacco transplanted at the normal date, similar to the four week delay in transplanting. Grade index was not affected by any treatment at Oxford in 2004.

At Clayton in 2003, total alkaloid levels were very low (16). All replanting treatments reduced total alkaloid levels below the already low levels observed in the controls. Because of the extremely wet conditions experienced in 2003 (Table 9), it is likely that replanting treatments further reduced soil structure and aeration and reduced over-all root growth and total alkaloid production (3). No differences in total sugars were observed at Clayton in 2003. No differences in total alkaloids were observed at either location in 2004 and total sugars were reduced with one treatment at each location in 2004.

Replanting treatments were imposed primarily to evaluate the effect of fertilizer application prior to replanting on replanted tobacco. During replanting, if roots of a tobacco transplant contact concentrated areas of fertilizer, transplant injury could occur. Contact of transplant roots with fertilizer may occur if the tobacco is replanted on the existing row ridge and transplants are placed in fertilizer that was previously banded in the row. Transplant roots may also contact fertilizer if re-bedding, or tilling and re-bedding, result in placement of the fertilizer in the root zone of the replanted tobacco. Excessive rainfall in 2003 and above average rainfall in 2004 likely prevented fertilizer injury to transplants. In 2003, however, replanting treatments imposed on excessively wet soils, likely reduced soil structure and aeration, therefore reducing over growth of tobacco compared to tobacco that was transplanted normally and had minimum soil disturbance. In 2004, when growing conditions were more favorable, replanting treatments were not consistently different from delayed transplanting treatments.

Plant Heights and Flowering Date

Plant height data were collected in 2004 only (Tables 12,13). Data were collected beginning four weeks after transplanting at Oxford and five weeks after transplanting at Clayton. At four and five weeks after transplanting at Oxford in 2004, there were no differences in plant height among treatments. Beginning six weeks after transplanting and continuing through topping, which occurred eight to ten weeks after transplanting, later planted tobacco grew at a faster rate than tobacco transplanted on the normal date. For example, seven weeks after transplanting, tobacco transplanted on the normal date had grown at an average rate of 5.4 cm per week. Tobacco transplanted two, three, four, and five weeks after transplanting had grown at a rate of 6.7, 7.7, 6.1, and 12.4 cm per week, respectively, at the same number of days after transplanting. The faster growth rate was more consistent, however, with the three, four, and five week delay in transplanting than with the two week delay and was not consistently affected by replanting treatment. At Clayton in 2004, all delayed planting treatments grew at a faster rate than tobacco transplanted at the normal date beginning with data collected five weeks after transplanting and continuing until flowering. Tobacco transplanted two and three weeks after the normal transplanting date grew at a faster rate than tobacco transplanted four or more weeks after the normal date. Slower growth seven weeks after transplanting with the four and five week transplanting delay compared to the two and three week delay is likely due to high temperature stress on the smaller plants due to late planting.

The number of days required to reach 50 % flower was highly variable and inconsistent at Clayton in 2003 and is again related to excessive rainfall. (Table 9) However, the faster growth rate associated with delayed transplanting resulted in a fewer days from transplanting until 50 % of the tobacco flowered for delayed transplanting treatments compared to tobacco transplanted at the normal date at the Clayton location in 2004 (Table 14). A 14 day (d) delay in transplanting resulted in a 3 d delay in flowering, a 21 d delay in transplanting resulted in a 9 d delay in flowering, a 28 d delay in transplanting resulted in a 16 d delay in flowering, and a 35 d delay in transplanting resulted in a 27 d delay in flowering compared to tobacco transplanted on the normal date. At Oxford in 2004, delayed transplanting did not reduce the number of days in the field required for flowering.(Table 14).

Summary

Research indicates that response to stand loss and transplanting date are highly dependent upon the growing season. In 2003, growing conditions were extremely poor due to cool temperatures early in the season and excessive rainfall throughout the season. Under those conditions, stand loss, planting date, and replanting method had little effect on yield and quality, and all yields were extremely low. In 2004, when conditions were more favorable for tobacco growth, yields were reduced with a 40 % stand loss that occurred gradually over the first five weeks after transplanting (TSW loss simulation), but were not reduced by stand losses up to 40 % that occurred at either two or four weeks after transplanting. Percent yield was reduced more by delaying transplanting four or five weeks after the normal transplanting date at OTRS in 2004 and by delaying transplanting five weeks at CCRS in 2004, than by any stand loss treatment. Because stand losses from TSW are gradual, by the time growers reach the levels of stand loss that significantly reduced tobacco yield in this experiment, yield loss associated with the late planting date would prohibit replanting from being a viable management option in most years.

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Table 3. Yield, quality, and value of tobacco with various stand loss treatments at Central Crops Research Station, 2003

Stand Loss	Weeks after Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
%		kg/ha	$/kg	$/ha		…..….. % ……….	
0	-	1327 a	3.40 ab	4531 a	48 ab	0.70 a	24.4 a
10	2	1538 a	3.23 bc	5003 a	40 bcd	0.75 a	24.7 a
20	2	1355 a	3.45 ab	4704 a	54 a	0.73 a	24.8 a
30	2	1369 a	3.37 ab	4653 a	42 bcd	0.78 a	25.4 a
40	2	1195 a	3.40 ab	4084 a	47 abc	0.75 a	25.0 a
10	4	1228 a	3.02 c	3766 a	43 bcd	0.69 a	25.4 a
20	4	1577 a	3.37 ab	5344 a	37 cd	0.69 a	25.3 a
30	4	1357 a	3.05 c	4175 a	36 d	0.72 a	25.2 a
40	4	1185 a	3.38 ab	4053 a	49 ab	0.71 a	25.0 a
40[3]	3,4,5	1468 a	3.48 a	5149 a	49 ab	0.91 a	24.5 a

[1] Means followed by the same letter are not significantly different.
[2] Based on U.S. Government grades; 1-100, with 100 being the best.
[3] TSW loss simulation which consisted of a 10%, 10%, and 20% loss at 3, 4, and 5 weeks after transplanting date, respectively.

Table 4. Yield, quality, and value of tobacco with various stand loss treatments at Central Crops Research Station, 2004

Stand Loss	Weeks after Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
%		kg/ha	$/kg	$/ha		…..….. %	……….
0	-	3017 ab	3.72 a	11,274 a	66 a	1.85 a	19.8 a
10	2	2975 ab	3.69 a	11,022 a	67 a	1.74 a	19.6 a
20	2	2718 bc	3.58 a	9,754 a	55 a	1.64 a	20.0 a
30	2	2814 bc	3.63 a	10,250 a	56 a	1.97 a	18.1 a
40	2	2762 bc	3.70 a	10,281 a	64 a	1.87 a	17.8 a
10	4	2911 ab	3.65 a	10,654 a	61 a	1.69 a	19.8 a
20	4	3198 a	3.69 a	11,831 a	63 a	1.54 a	19.7 a
30	4	2761 bc	3.62 a	10,019 a	56 a	1.84 a	19.1 a
40	4	2787 bc	3.71 a	10,365 a	63 a	1.96 a	18.5 a
40[3]	3,4,5	2433 c	3.74 a	9,138 a	64 a	1.66 a	19.8 a

[1] Means followed by the same letter are not significantly different.
[2] Based on U.S. Government grades; 1-100, with 100 being the best.
[3] TSW loss simulation which consisted of a 10%, 10%, and 20% loss at 3, 4, and 5 weeks after transplanting date, respectively.

Table 5. Yield, quality, and value of tobacco with various stand loss treatments at Oxford Tobacco Research Station, 2004

Stand Loss	Weeks after Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
%		kg/ha	$/kg	$/ha		…..….. %	………
0	-	3622 a	3.72 a	13552 a	62 a	2.21 a	24.6 a
10	2	3676 a	3.70 a	13664 a	62 a	2.18 a	25.6 a
20	2	3690 a	3.72 a	13778 a	63 a	2.28 a	24.5 a
30	2	3782 a	3.77 a	14275 a	72 a	2.19 a	24.0 a
40	2	3539 a	3.77 a	13397 a	64 a	2.17 a	24.9 a
10	4	3803 a	3.74 a	14271 a	64 a	2.36 a	22.3 a
20	4	3413 a	3.74 a	12820 a	63 a	2.50 a	24.3 a
30	4	3321 a	3.72 a	12411 a	62 a	2.76 a	22.0 a
40	4	3406 a	3.71 a	12679 a	61 a	2.15 a	24.6 a
40[3]	3,4,5	3272 a	3.73 a	12238 a	56 a	2.66 a	22.5 a

[1] Means followed by the same letter are not significantly different.
[2] Based on U.S. Government grades; 1-100, with 100 being the best.
[3] TSW loss simulation which consisted of a 10%, 10%, and 20% loss at 3, 4, and 5 weeks after transplanting date, respectively.

Table 6. Yield, quality, and value of tobacco with various transplanting dates and replanting methods at Central Crops Research Station, 2003

Transplanting Method	Timing of Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
	delay in weeks	kg/ha	$/kg	$/ha		…..….. %	……….
Normal	none	1469 ab	3.39 abc	5001 ab	41 bc	0.83 a	23.1 a
Normal	2	1232 b-e	3.38 abc	4174 bc	39 bc	0.72 abc	22.4 a
Replant on existing row ridge	2	1255 bcd	3.25 bcd	4094 bc	37 bc	0.61 b-e	23.4 a
Rebed and Replant	2	1172 c-f	3.32 a-d	3897 bcd	36 c	0.55 cde	22.9 a
Till, Rebed, and Replant	2	963 efg	3.23 bcd	3148 cde	38 bc	0.48 e	22.7 a
Normal	3	1465 ab	3.31 a-d	4892 ab	47 ab	0.67 a-d	23.2 a
Normal	4	1637 a	3.56 a	5852 a	57 a	0.80 a	21.9 a
Replant on existing row ridge	4	911 fg	3.16 cd	2882 de	41 bc	0.58 cde	22.0 a
Rebed and Replant	4	1047 d-g	3.15 cd	3339 cde	37 bc	0.51 de	22.2 a
Till, Rebed, and Replant	4	861 g	3.09 d	2680 e	45 bc	0.45 e	22.5 a
Normal	5	1398 abc	3.48 ab	4873 ab	57 a	0.78 ab	20.0 a

[1] **Means followed by the same letter are not significantly different.**
[2] **Based on U.S. Government grades; 1-100, with 100 being the best.**

Table 7. Yield, quality, and value of tobacco with various transplanting dates and replanting methods at Oxford Tobacco Research Station, 2004

Transplanting Method	Timing of Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
	delay in weeks	kg/ha	$/kg	$/ha		…..….. %	……….
Normal	none	4006 abc	3.58 a	14399 ab	61 a	1.84 a	20.4 ab
Normal	2	4049 ab	3.64 a	14790 ab	56 a	1.63 a	21.4 a
Replant on existing row ridge	2	4288 a	3.49 a	15017 ab	58 a	1.70 a	21.3 a
Rebed and Replant	2	4485 a	3.67 a	16507 a	56 a	1.59 a	20.2 ab
Till, Rebed, and Replant	2	4497 a	3.53 a	15954 a	53 a	1.64 a	17.7 c
Normal	3	3543 bcd	3.57 a	12717 bc	54 a	1.81 a	20.9 a
Normal	4	2789 e	3.39 a	9476 d	53 a	1.65 a	19.7 ab
Replant on existing row ridge	4	3084 de	3.39 a	10486 cd	51 a	1.57 a	21.4 a
Rebed and Replant	4	2925 de	3.52 a	10532 cd	59 a	1.53 a	20.4 ab
Till, Rebed, and Replant	4	3388 cde	3.11 a	10780 cd	43 a	1.62 a	20.7 ab
Normal	5	2906 e	3.16 a	9152 d	52 a	1.61 a	18.9 bc

[1] Means followed by the same letter are not significantly different.
[2] Based on U.S. Government grades; 1-100, with 100 being the best.

Table 8. Yield, quality, and value of tobacco with various transplanting dates and replanting methods at Central Crops Research Station, 2004

Transplanting Method	Timing of Transplanting	Yield[1]	Price[1]	Value[1]	Grade index[1,2]	Total alkaloids[1]	Total sugars[1]
	delay in weeks	kg/ha	$/ kg	$/ha		…..….. %	……….
Normal	none	3507 a	3.78 a	13353 ab	68 abc	2.51 a	21.2 abc
Normal	2	3497 ab	3.76 a	13200 ab	69 abc	2.15 a	20.3 abc
Replant on existing row ridge	2	3636 a	3.77 a	13798 a	70 abc	2.03 a	21.0 abc
Rebed and Replant	2	3489 ab	3.76 a	13166 ab	70 ab	2.23 a	16.2 d
Till, Rebed, and Replant	2	3430 ab	3.82 a	13164 ab	74 a	2.10 a	18.5 cd
Normal	3	3640 a	3.70 ab	13479 a	62 bcd	2.08 a	22.5 a
Normal	4	3285 ab	3.58 b	11781 bc	57 cd	2.20 a	19.9 abc
Replant on existing row ridge	4	3068 b	3.56 b	10977 c	55 d	2.18 a	20.7 abc
Rebed and Replant	4	3060 b	3.60 b	11066 c	59 bcd	2.18 a	21.9 ab
Till, Rebed, and Replant	4	3424 ab	3.59 b	12342 abc	53 d	2.12 a	21.8 ab
Normal	5	2404 c	3.59 b	8667 d	61 bcd	2.01 a	19.3 bcd

[1] **Means followed by the same letter within columns are not significantly different.**
[2] **Based on U.S. Government grades; 1-100, with 100 being the best.**

Table 9. Temperature and rainfall data from Central Crops Research Station, 2003

Weeks after transplanting	Average High Temperature	Average Low Temperature	Total Precipitation
	…………….°C…………….		cm
0	24	12	0.99
1	24	14	0.81
2	29	17	0.00
3	22	13	3.18
4	23	15	3.43
5	25	15	1.07
6	29	18	2.64
7	29	21	2.97
8	29	18	1.04
9	30	20	8.23
10	32	22	0.86
11	30	21	5.44
12	30	21	9.70
13	31	21	1.42
14	30	21	8.36
15	29	22	6.10
16	30	21	7.92
17	32	21	0.00
18	33	22	0.33
19	26	17	1.93
20	26	16	0.03
21	27	17	6.78

Table 10. Temperature and rainfall data from Central Crops Research Station, 2004

Weeks after transplanting	Average High Temperature	Average Low Temperature	Average Temperature	Total Precipitation
	……………...…….°C…………...……….			cm
0	25	11	18	1.47
1	24	13	18	5.16
2	29	17	23	0.00
3	30	18	24	0.56
4	32	21	26	0.84
5	28	19	24	4.83
6	29	19	23	2.79
7	29	21	24	0.43
8	30	22	25	4.42
9	29	20	24	1.70
10	33	22	27	0.66
11	32	21	26	3.63
12	31	20	25	2.59
13	30	22	25	6.53
14	30	21	25	3.71
15	28	17	23	1.73
16	27	19	23	11.9
17	29	19	24	1.14
18	28	20	23	8.84
19	28	21	24	3.53
20	26	18	22	0.33
21	24	14	18	0.58

Table 11. Temperature and rainfall data from Oxford Tobacco Research Station, 2004

Weeks after transplanting	Average High Temperature	Average Low Temperature	Average Temperature	Total Precipitation
	……………..…….	°C…………..……….		cm
0	29	17	22	0.00
1	26	16	20	1.98
2	30	20	24	3.05
3	27	17	22	1.45
4	29	19	23	2.44
5	30	21	25	1.02
6	29	19	23	1.65
7	29	19	23	0.69
8	34	21	27	0.56
9	32	20	25	2.49
10	30	20	24	7.90
11	30	21	24	11.38
12	29	19	23	3.73
13	27	17	22	2.64
14	24	17	20	6.93
15	29	18	23	0.56
16	28	19	23	5.74
17	28	20	23	3.73
18	25	17	21	0.76
19	25	12	18	2.46
20	21	14	17	1.50

Table 12. Plant heights at different timings after transplanting at Central Crops Research Station, 2004

Transplanting Method	Timing of Transplanting	Weeks After Transplanting[1,2] 5	6	7	8	9
	delay in weeks	……………………….height (cm)…………..……..……				
Normal	none	11 c	38 f	45 d	63 c	118
Normal	2	39 ab	58 de	110 b		
Replant on existing row ridge	2	39 ab	60 cd	110 b		
Rebed and Replant	2	40 ab	59 cd	111 b		
Till, Rebed, and Replant	2	43 a	67 ab	123 a		
Normal	3	36 b	71 a	109 b	122 b	
Normal	4	39 ab	63 bcd	81 c	133 ab	
Replant on existing row ridge	4	39 ab	64 bcd	81 c	129 ab	
Rebed and Replant	4	43 a	69 a	88 c	137 a	
Till, Rebed, and Replant	4	41 a	65 abc	83 c	137 a	
Normal	5	36 b	53 e	84 c	139 a	

[1] Means followed by the same letter are not significantly different.
[2] Plant heights were measured until plants flowered.

Table 13. Plant heights at different timings after transplanting at Oxford Tobacco Research Station, 2004

		Weeks After Transplanting[1,2]					
Transplanting Method	**Timing of Transplanting**	**4**	**5**	**6**	**7**	**8**	**9**
	delay in weeks	……………………….height (cm)…………..…….……					
Normal	none	7 a	17 a	27 cd	38 g	73 de	96 e
Normal	2	8 a	16 a	34 abc	47 efg	70 e	116 bcd
Replant on existing row ridge	2	9 a	17 a	36 ab	49 def	74 de	120 bc
Rebed and Replant	2	9 a	16 a	35 abc	52 c-f	76 de	122 bc
Till, Rebed, and Replant	2	8 a	14 a	27 bcd	43 fg	63 e	105 de
Normal	3	10 a	22 a	36 ab	54 b-e	97 bc	139 a
Normal	4	8 a	14 a	22 d	43 fg	90 cd	116 bcd
Replant on existing row ridge	4	10 a	10 a	28 bcd	58 bcd	114 ab	119 bcd
Rebed and Replant	4	9 a	9 a	30 bcd	62 bc	113 ab	130 ab
Till, Rebed, and Replant	4	10 a	10 a	31 bc	64 b	123 a	114 cd
Normal	5	11 a	11 a	40 a	87 a	107 abc	

[1] Means followed by the same letter are not significantly different.
[2] Plant heights were measured until plants flowered.

Table 14. Number of days required to reach fifty percent flower at three locations over two years.

Transplanting Method	Timing of Transplanting	Clayton 2003	Clayton 2004	Oxford 2004
	delay in weeks		Number of Days to 50% Flower[1]	
Normal	none	59 bcd	65 d	58 a
Normal	2	63 ef	54 abc	62 a
Replant on existing row ridge	2	60 cde	54 abc	59 a
Rebed and Replant	2	65 f	54 abc	56 a
Till, Rebed, and Replant	2	63 ef	54 abc	61 a
Normal	3	54 a	53 ab	60 a
Normal	4	58 bcd	53 ab	61 a
Replant on existing row ridge	4	59 bcd	52 a	60 a
Rebed and Replant	4	58 bc	53 ab	60 a
Till, Rebed, and Replant	4	57 ab	56 bc	59 a
Normal	5	60 cde	57 c	56 a

[1] Means followed by the same letter are not significantly different.