The Effects of Plant Population on Agronomic Characteristics of Burley Tobacco

Bob Miller
Kentucky-Tennessee Tobacco Improvement Initiative

Research Report Submitted to the Council for Burley Tobacco
January 15, 2015

Introduction:
In July 2013, the Council for Burley Tobacco funded a research project to investigate the effects of plant spacing on the handling characteristics and yield of burley tobacco. Several growers had commented that new burley varieties tended to be large and hard to handle, yet yields were often lower than those obtained 15-20 years ago. However, data collected in University conducted commercial variety trials demonstrate that the newer varieties have comparable or superior yields when grown in the absence of disease, and are far superior where black shank is a factor. One major factor determining plant size and yield/acre that is often overlooked by growers is plant population, which has tended to decrease substantially for many growers over the last twenty years. As in-row plant spacing increases, the plant population decreases. Previous research studies have demonstrated that as plant spacing increases, individual plants get larger, heavier, and harder to handle; although individual plant yield also increases, overall yield per acre declines substantially due to the decreased number of plants.

Although the project was funded in July, 2013, the field research was conducted during the 2014 growing season. The study was conducted at four locations; Lexington, KY; Versailles, KY; Greeneville, TN; and Springfield, TN. However, the study at Lexington was devastated by a severe hailstorm that occurred on July 27 (**Photos 1 and 2**). As a result, all of the 2014 KTTII research plots at Lexington had to be abandoned. A second, less severe hailstorm damaged the research plots at Greeneville, TN, on August 20. This storm hit one week before the tobacco was scheduled to be harvested. Although the damage was less severe, there was a significant amount of leaf breakage, particularly in the top of plants. This resulted in a large number of leaves being left on the ground during after harvest, which will undoubtedly significantly reduce yields (**Photo 3 and 4**). However, it is assumed that all spacing treatments were adversely affected more or less equally and that comparative data will still be useful.

Photo 1. Hail damage, 1 week after topping

Photo 2. Hail damage, tobacco transplanted 4 wks

Photo 3. Hail Damage, Greeneville, TN, August 20

Photo 4. Leaf loss due to hail damage, Greeneville

Research Format:

Two varieties, TN 90 LC and KT 206LC, were used for the study. TN 90 is a relatively small variety that is particularly easy to handle but had a seven year average yield of only 2,897 Lbs/A in commercial variety trials. KT 206LC is a larger variety that can be hard to handle under good growing conditions but had a seven year average yield of 3,171 Lbs/A. Four plant populations were evaluated: 8297 Plts/A (42" row width/18" plant spacing); 7128 Plts/A (42"/ 21"); 6223 Plts/A (42"/24"); and 5234 Plts/A (42"/28"). Four row plots were used, with data being collected from only the two center rows; this was done to ensure that a "next row neighbor" did not affect the performance of a particular

spacing treatment (e.g., if data were collected from an 18" spacing, results could be completely different if the neighboring row had 28" spacing rather than an 18"spacing). At the Greeneville and Versailles locations, agronomic data were collected for stalk size and weight per plant at pick up three days after cutting. After stripping, yield data was collected from all locations except Lexington.

Results:

The data for the effects of plant spacing on stalk size at the cut base of the plant and weight of single plants three days after cutting are presented in **Table 1**. As expected, the data verify that KT 206LC produces a larger plant than TN 90LC, regardless of plant spacing. The average stalk circumference for KT 206LC across plant populations and locations was 4.02 inches versus 3.86 inches for TN 90LC; the average weight of a single plant of KT 206LC was 4.12 lbs versus 3.47 for TN 90LC at pick-up three days after cutting. Surprisingly, the stalk circumference and plant weight of KT 206LC was affected by plant spacing to a larger extent than was TN 90LC. The average difference in stalk circumference between the 18 and 28 inch spacing treatments was 0.57 inches for KT 206LC, compared to 0.30 inches for TN 90LC. At the 18 inch spacing, the stalk size of KT 206 was approximately the same as for TN 90LC. The difference in plant weight between the varieties at the 18" spacing was 0.17 pounds per plant. In contrast, at the 28" spacing the difference between KT 206LC and TN 90LC was 0.18" for stalk circumference and 0.67 lbs for plant weight.

Table 1. Effect of Plant Population on Stalk Size and Weight

Plant Spacing	Population Plants/ Acre	Stalk Circumference at Base (Inches)			Single Stalk Wt.* (Lbs)		
Greeneville, TN							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	3.98	4.05	**4.02**	3.11	2.83	**2.97**
21	7128	4.37	4.01	**4.19**	3.89	2.78	**3.33**
24	6223	4.36	4.14	**4.25**	3.81	3.00	**3.40**
28	5234	4.53	4.21	**4.37**	3.87	3.24	**3.56**
Mean		**4.31**	**4.10**		**3.67**	**2.96**	
Versailles, KY							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	3.42	3.43	**3.43**	3.78	3.71	**3.74**
21	7128	3.81	3.45	**3.63**	4.62	3.60	**4.11**
24	6223	3.69	3.68	**3.69**	4.76	4.07	**4.42**
28	5234	4.02	3.88	**3.95**	5.10	4.49	**4.79**
Mean		**3.74**	**3.61**		**4.56**	**3.97**	
Two Location - Mean							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	**8297**	**3.70**	**3.74**	**3.72**	**3.44**	**3.27**	**3.36**
21	**7128**	**4.09**	**3.73**	**3.91**	**4.26**	**3.19**	**3.72**
24	**6223**	**4.02**	**3.91**	**3.97**	**4.28**	**3.54**	**3.91**
28	**5234**	**4.27**	**4.04**	**4.16**	**4.49**	**3.87**	**4.18**
Mean		**4.02**	**3.86**		**4.12**	**3.47**	

The impact of increased plant size on the weight of sticks of tobacco at loading and housing are presented in **Table 2**. At the 18" spacing, the average stick weight of KT 206LC exceeded the stick weight of TN 90L by 0.88 pounds per five stalk stick, or 1.05 pounds per six stalk stick, which is fairly insignificant. In contrast, the average difference in weight between the two varieties when grown at the 28" spacing was 3.25 pounds for a five stalk stick or 3.91 pounds for a six stalk stick. Undoubtedly, the difference in weight between a single stalk of KT 206LC versus TN 90LC at cutting was substantially greater than it was three days after cutting, making handling characteristics between the two varieties greater than the data here suggest. This data suggests that an 18" in row spacing may limit the genetic potential for stalk size for KT 206LC. If that is in fact true, producers who prefer the handling characteristics of TN 90LC, but need to grow one of the newer KT varieties in order to take advantage of their higher resistance to race 1 black shank, may need to use an 18" spacing to make the size of plants more manageable. This will be discussed in more detail later in this report.

Table 2. Effect of Plant Population on Stick Weight

Plant Spacing	Population Plants/ Acre	5 Stalk Stick Wt.* (Lbs)			6 Stalk Stick Wt.* (Lbs)		
* Weight after field wilting for three days							
		Greeneville					
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	15.55	14.13	14.84	18.66	16.95	17.81
21	7128	19.44	13.91	16.67	23.32	16.69	20.01
24	6223	19.03	14.99	17.01	22.84	17.99	20.41
28	5234	19.36	16.21	17.79	23.23	19.46	21.35
Mean		**18.35**	**14.81**		**22.01**	**17.77**	
		Versailles, KY					
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	18.89	18.56	18.72	22.66	22.28	22.47
21	7128	23.12	18.00	20.56	27.74	21.61	24.67
24	6223	23.79	20.37	22.08	28.55	24.44	26.50
28	5234	25.49	22.45	23.97	30.59	26.94	28.77
Mean		**22.82**	**19.85**		**27.39**	**23.82**	
		Two Location - Mean					
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	17.22	16.34	16.78	20.66	19.61	20.14
21	7128	21.28	15.96	18.62	25.53	19.15	22.34
24	6223	21.41	17.68	19.55	25.69	21.22	23.46
28	5234	22.43	19.33	20.88	26.91	23.20	25.06
Mean		**20.58**	**17.33**		**24.70**	**20.79**	

Yield data from the three locations that were able to be harvested are presented in **Table 3**. As expected, KT 206LC produced higher yields than TN 90LC for every treatment at all locations, with the average yield of KT 206LC being 256 lbs/A higher than TN 90LC. Although there was variability between locations, yield/plant increased with wider plant spacing, but yield/acre tended to decrease.

Table 3. Effect of Plant Population on Yield

Plant Spacing	Population Plants/ Acre	Weight per Plant (Lbs)			Yield/AcreYield per Acre (Lbs)		
Versailles, Ky							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	0.42	0.38	**0.40**	3514	3182	**3348**
21	7128	0.48	0.39	**0.44**	3418	2795	**3107**
24	6223	0.49	0.46	**0.48**	3074	2877	**2976**
28	5234	0.56	0.53	**0.55**	2994	2820	**2907**
Mean		**0.49**	**0.44**		**3250**	**2919**	
Greeneville							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	0.34	0.33	**0.34**	2806	2716	**2761**
21	7128	0.40	0.35	**0.38**	2880	2489	**2685**
24	6223	0.41	0.36	**0.39**	2578	2244	**2411**
28	5234	0.41	0.37	**0.39**	2204	1994	**2099**
Mean		**0.39**	**0.35**		**2617**	**2361**	
Springfield							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	0.32	0.31	**0.32**	2684	2559	**2622**
21	7128	0.36	0.34	**0.35**	2583	2440	**2512**
24	6223	0.45	0.42	**0.44**	2773	2634	**2704**
28	5234	0.51	0.46	**0.49**	2746	2439	**2593**
Mean		**0.41**	**0.38**		**2697**	**2518**	
Three Location - Mean							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	0.33	0.32	**0.33**	3001	2819	**2910**
21	7128	0.38	0.35	**0.36**	2960	2575	**2768**
24	6223	0.43	0.39	**0.41**	2808	2585	**2697**
28	5234	0.46	0.42	**0.44**	2648	2418	**2533**
Mean		**0.40**	**0.37**		**2855**	**2599**	

At the Versailles location, the decrease in yield for KT 206LC was more or less linear as plant spacing increased, but yield did not change substantially for TN 90LC once plant spacing exceeded 21". At Greeneville, individual plant yield did not increase with increased plant spacing as much as it did at the other two locations, which resulted in a much greater decrease in yield/acre as plant population decreased. This may have been due to the hail damage that occurred one week prior to harvest. Although it was initially assumed that the decrease in yield due to leaf loss at harvest would be fairly uniform across plant spacing, that assumption very likely was not true. As plant spacing increases, the growth habit of the plants changes substantially. Increased spacing leads to plants that have larger leaves that tend to droop rather than having the erect growth habit observed at higher plant

populations; as a result leaf loss due to hail was likely greater due to the prostrate rather than erect leaf architecture present at wider plant spacings. Conversely, at Springfield individual plant yield increased substantially as plant spacing decreased. These much larger yields per individual plant tended to largely off-set the decreased plant population to the point that yield per acre was not consistently reduced, particularly for KT 206LC. Historically, the Springfield location produces significantly lower yields of burley tobacco in comparison to Greeneville or Versailles. These three locations have distinctly different soil types, which may partially explain the differing yield response to increased plant spacing. Another possible explanation is that Springfield, TN is historically a dark tobacco production area, which is grown at a much wider plant spacing than traditional burley spacing. As a result, management of burley tobacco with regard to fertilization and topping heights often tends to be similar to dark tobacco, which may favor wider plant spacing.

One of the questions this study was designed to answer was whether increasing the plant population could make large, high yielding, disease resistant varieties easier to handle; for example, how would the size and yield of KT 206LC at an 18 or 21 inch spacing compare to the size and yield of TN 90LC at a 24 or 28 inch spacing? To allow a direct comparison between the agronomic characteristics of the two varieties at different plant spacings, a summary of the data presented in previous Tables is presented in **Table 4**. The direct comparison between KT 206LC at an 18" spacing versus TN 90LC at a 24" spacing is highlighted in yellow. As can be seen by the data, stalk size and plant weight of individual plants are less for KT 206LC at an 18" spacing compared to TN 90 at a 24" spacing. The yield of individual KT 206LC plants decreased, but because of the increased number of plants the yield per care of KT 206LC at an 18" spacing is 416 lbs/A greater than TN 90LC at a 24" spacing. This suggests that for growers who need higher levels of black shank resistance provided by KT 206LC in comparison to TN 90LC, but prefer the handling characteristics of TN 90LC, decreasing plant spacing may be something to be considered. Because the growth characteristics of KT 204LC, KT 209LC, and KT 210LC are much more similar to KT 206LC than they are to TN 90LC, the data from the present study suggest that by adjusting plant spacing, any of these varieties can be utilized to handle severe soil-borne diseases without producing plants that are too large to handle at harvest.

There is no "one size fits all" plant population; the optimal plant population for an individual grower will depend on parameters such as whether land and barns are owned or leased; whether labor is paid by the hour, by the stick, or by the acre; price received for the tobacco; whether variety choice is dictated by disease resistance requirements; etc. In general, labor inputs and barn space requirements increase as plant population increases, while fertilizer, chemical inputs, and land requirements are decreased. Although labor data were not collected as part of the current study, a large study was conducted several years ago by Dr. Steve Isaacs, currently an UK Agricultural Economics Extension Professor, to help individual growers determine the plant population that will work best for their particular production situation. That study was conducted by Dr. Isaacs as part of his Ph.D. research at the University of Tennessee. Labor data include all operations from transplant production to marketing.

Table 4. Comparison of KT 206LC at 18" Spacing versus TN 90LC at 24" Spacing

Stalk Size and Weight							
Plant Spacing	Population Plants/ Acre	Stalk Circumference (Inches)			Single Stalk Wt. (Lbs)		
* Weight after field wilting for three days							
		Mean for Greeneville and Versailles					
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	3.70	3.74	3.72	3.44	3.27	3.36
21	7128	4.09	3.73	3.91	4.26	3.19	3.72
24	6223	4.02	3.91	3.97	4.28	3.54	3.91
28	5334	4.27	4.04	4.16	4.49	3.87	4.18
Mean		4.02	3.86		4.12	3.47	

Stick Weight							
Plant Spacing	Population Plants/ Acre	5 Stalk Stick Wt.* (Lbs)			6 Stalk Stick Wt.* (Lbs)		
* Weight after field wilting for three days							
		Mean for Greeneville and Versailles					
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	17.22	16.34	16.78	20.66	19.61	20.14
21	7128	21.28	15.96	18.62	25.53	19.15	22.34
24	6223	21.41	17.68	19.55	25.69	21.22	23.46
28	5334	22.43	19.33	20.88	26.91	23.20	25.06
Mean		20.58	17.33		24.70	20.79	

Yield							
Plant Spacing	Population Plants/ Acre	Yield per Plant (Lbs)			Yield per Acre (Lbs)		
Mean for Versailles, KY and Greeneville and Springfield, TN							
		KT 206LC	TN 90LC	MEAN	KT 206LC	TN 90LC	MEAN
18	8297	0.33	0.32	0.33	3001	2819	2910
21	7128	0.38	0.35	0.36	2960	2575	2768
24	6223	0.43	0.39	0.41	2808	2585	2697
28	5334	0.46	0.42	0.44	2648	2418	2486

The labor requirements determined for tobacco production from Dr. Isaacs' research study can be combined with yield data from the current research conducted in 2014 to give some insight as to how labor requirements are affected by plant spacing (**Table 5**). However, the Isaacs study and the 2014 research reported here were conducted in different production eras. Dr. Isaac's research was conducted from 1987-1990 using TN 86 as the variety. The study was conducted prior to the advent of hydroponic transplant production, and the tobacco was cut using the two man team approach common in TN at that time. Therefore the labor data presented in Table 5 should be considered only for comparative purposes rather than as absolute values.

Table 5. Estimated Labor Requirements

Variable	Plant Spacing (42" Row Spacing)			
	18"	21"	24"	28"
Plants/Acre	8297	7128	6223	5334
Sticks/A (5 stalks)	1659	1426	1245	1067
Sticks/A (6 Stalks)	1383	1188	1037	889
Labor Requirements (man hours)*				
Hours/Acre	206	184	167	149
Hrs/1000 Sticks (5 Stalks)	124	129	134	140
Hrs/1000 Sticks (6 Stalks)	149	155	161	168
Man Hours Required per 100lbs Yield Produced				
KT 206LC				
Yield/Acre	3001	2960	2808	2648
Labor Hrs/100lbs	6.9	6.2	5.9	5.6
TN 90LC				
Yield/Acre	2819	2575	2585	2418
Labor Hrs/100lbs	7.3	7.1	6.4	6.2

*Labor data are taken from research conducted by Dr. Steve Isaacs at the University of Tennessee from 1987-1990 as part of his Ph.D. research. The variety used in that study was TN 86. Labor data include all operations from transplant production to marketing. However, because the research was conducted prior to the advent of hydroponic transplant production and because the tobacco was cut using the two man team approach common in TN at that time, labor data should be considered only for comparative purposes rather than as absolute values.

With those limitations in mind, it is obvious from **Table 5** that labor hours required per acre decrease as plant population decreases. Conversely, labor required per 1000 sticks harvested increases slightly as plant spacing increases. This is due to larger, harder to handle plants; a second likely factor is that as spacing between plants increase, there is more wasted motion during the cutting process.

Perhaps more importantly, the amount of labor required to produce 100 pounds of marketable tobacco decreases as plant spacing increases. However, although this would certainly decrease labor costs, it does not necessarily increase profits. For example, based on labor estimates from the Isaacs study and yields from the current study, it requires 6.9 hours of labor to produce 100 lbs of KT 206LC grown at an 18" spacing, compared to 6.4 hours of labor to produce 100 lbs of TN 90LC grown at a 24" spacing (values highlighted in yellow in Table 5). Based on these figures, it would require a total of 207 man hours to produce 3001 lbs of KT 206LC at an 18" spacing, compared to 165 man hours to produce 2585 lbs of TN 90LC at a 24" spacing. If labor cost $10/hr, the 42 additional hours required to produce the KT 206LC crop would cost $420. However, if the tobacco sold for $2.00/lb, the additional 416 lbs of yield from the KT 206LC crop would gross $832 in comparison to the TN 90LC crop, which is almost double the cost of additional labor required.

As stated earlier, there is no one plant spacing that is ideal for every situation. What is apparent from the 2014 research project that was funded by the Council for Burley Tobacco is that as plant

population increased, plants became larger and harder to handle and yields tend to decrease, particularly at Greeneville and Versailles. By using yield data and relative labor estimates from this research, growers should be able to use the **Burley Tobacco Budget Worksheets** provided by the University of Kentucky Agricultural Economics Department to determine appropriate plant populations to use for their unique production needs and practices. The Web address for the budget worksheets is: **http://www2.ca.uky.edu/agecon/Index.php?p=260** .