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AGRONOMY

Measuring Maturity of Cotton Using Nodes above White Flower

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INTERPRETIVE SUMMARY

Enhancing earliness without sacrificing yield has been a goal in cotton research programs since the early 1900s. Typically, crop maturity has been evaluated by sequentially harvesting seedcotton and comparing yields at each harvest with final yield. The most commonly used of these maturity measurements are percentage of crop harvested in the first of two harvests (% first pick) and mean maturity date. The % first pick measurement cannot be used to compare maturity among tests. Also, differences in maturity are lessened and become more obscure as the first of two harvests is delayed. Requiring multiple harvests, mean maturity date becomes more precise as the number of harvests increases. Because these measurements are based on harvest data, they cannot be used for in-season management and are easily skewed by factors that either cause premature boll opening (e.g., Verticillium wilt) or prevent boll opening (e.g., cool temperatures).

As a cotton plant matures, the addition of nodes in the plant apex slows, then ceases, due to the increased assimilate demand for fruit development. Consequently, first-position white flowers occur progressively closer to the plant apex until flowering ceases. Physiological cutout (cessation of effective flowering) has been determined to occur when nodes above white flower is equal to 5.0. Sequential monitoring of nodes above white flower can be used to determine the number of days from planting until nodes above white flower = 5.0 (physiological cutout date). The objective of this research was to evaluate physiological cutout date as a measure of maturity by comparing it with harvest-based maturity measurements.

We used data from three different field tests in which nodes above white flower counts and multiple harvests were available to compare the maturity measurements. Generally, measurements of physiological cutout date were closely related to harvest-based measurements. Exceptions occurred when mean values of % first pick exceeded 90% and when Verticillium wilt caused premature boll opening. Data indicate that the physiological cutout date provides a measure of crop maturity that is not confounded by boll opening conditions nor by timing of harvests. Relative maturity of cotton over time (different years) and space (different fields and tests) can be compared with physiological cutout date, because the latter is expressed in standard units of days from planting. Also, because physiological cutout date is determined during the season, it provides a convenient and timely measure of crop maturity.

ABSTRACT

Due to its indeterminate growth habit, maturation of cotton (*Gossypium hirsutum* L.) is affected by many environmental and cultural factors. An easy and reliable measure of its progression toward maturity that can be attained during crop development is needed for both production and research programs. As a cotton plant develops, first-position flowers progress toward the plant apex, and their relative position can be determined by counting the number of main-stem nodes above the uppermost white flower. After plants attain nodes above white flower = 5.0 (physiological cutout date; i.e., flowering date of the last effective boll population), subsequent flowers have a low probability of producing bolls of adequate size and quality. The objective of this study was to evaluate physiological cutout date (days from planting to physiological cutout) as a measure of maturity in cotton by comparing it with two established harvest-based methods: mean maturity date and percentage of crop harvested in the first of two harvests (% first

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pick). Comparisons were made in three tests: (i) evaluation of varying treatments for thrips (*Frankliniella* spp.), (ii) nitrogen rate on three cultivars, (iii) cultivar evaluation at different locations in Arkansas. Within each test, sequential nodes above white flower counts were used to determine physiological cutout date, while mean maturity date (days from planting until 50% yield can be harvested), and % first pick were determined from sequential harvests. Significant variation was found within each test for all of the maturity measurements. Physiological cutout date tended to be closely related to mean maturity date and % first pick. Exceptions occurred when values of % first pick exceeded 90% (variation in maturity was not expressed) and when Verticillium wilt (caused by *Verticillium dahliae* Kleb.) affected crop maturity after physiological cutout. Thus, physiological cutout date provides a precise, easy, and reliable measurement of the accumulated effects of environmental and cultural factors on crop development that occurs before the flowering of the last effective boll population.

Early crop maturation and harvest of cotton can enhance production efficiency by alleviating late-season risks associated with insect problems and adverse weather (Anderson et al., 1976). Various measurements have been used to evaluate earliness of cotton. Richmond and Radwan (1962) found that phenological (first square, flower, and open boll) and product-quantity measurements (ratios of fractions relative to total yield) of earliness were significantly correlated. They suggested that the most practical method by which to measure maturity involved examining the ratio of weights in early harvests to total seedcotton harvested.

Although percentage of total crop yield harvested in the first of two harvests (% first pick) has been the most frequently used measurement of earliness, it has disadvantages. First, data from different tests cannot be compared directly because values depend on when the first harvest was made. Second, variation in maturity may be masked by delayed harvests, such as when average first pick exceeds 90%. Third, the use of boll-openers (e.g., ethephon [2-chloroethylphosphonic acid]) has frequently led to once-over harvesting, thus negating the time and expense of second-harvest as well as eliminating the possible use of % first pick as a measure of maturity.

Richmond and Ray (1966) found that mean maturity date provided a more exact measurement of earliness than did percentages of total harvest in multiple harvests. Mean maturity date is determined by multiplying sequential yield weights by days from planting, then dividing by total yield. Thus, mean maturity date directly measures realized maturity of the crop and quantifies maturity in a meaningful, comparable unit; i.e., number of days from planting to harvest. However, mean maturity date requires multiple harvests with its accuracy enhanced as number of harvests increases, and it cannot be calculated until after harvests are completed.

As boll load increases, maturation of cotton plants is signaled by slowed development of new main-stem nodes, which causes first-position white flowers to appear progressively closer to the plant apex (Oosterhuis et al.,1992). Waddle (1974) was the first to report the use of node number of first-position white flower relative to the plant apex as an indicator of maturity in cotton. Comparing cultivars that differed in maturation time, he observed that earlier maturing cultivars had fewer nodes above the last white flower during the third and fourth weeks of flowering than did later maturing cultivars. Furthermore, he indicated that "it is reasonable to expect that the number of nodes above the last white bloom will be an excellent herald for cutout and a general growth indicator for any one variety." Sequential measurements of this plant parameter, now referred to as nodes above white flower, can be used to monitor the development and maturation of cotton (Bourland et al., 1992).

Within the COTMAN expert system, physiological cutout has been defined as the flowering date of the last effective flower population, as determined by an average nodes above white flower of 5.0 (Oosterhuis et al., 1996). Flower retention and subsequent boll size decline rapidly when flowers occur five nodes (and closer) from the plant terminal. If nodes above white flower = 5.0 is attained after the latest possible cutout date (based on historical weather data, the latest date from which sufficient heat likely will be available to mature a population of bolls), seasonal cutout is indicated. Maturity is then determined by weather limitations rather than crop maturation, because late-developing flowers (even those that occur at nodes above white flower $\geq$ 5.0) will not have time to develop into economically viable bolls.

Crop maturity, as defined by the date that physiological cutout occurs, can be determined from multiple measurements of nodes above white flower and expressed as days from planting to nodes above white flower = 5.0 (physiological cutout date). Like mean maturity date, physiological cutout date may provide a temporal measure of maturity that can be compared among diverse environments, but it does not require multiple harvests.

Determination of maturity based on harvest data, as done with % first pick or mean maturity date, precludes in-season management that is based on crop maturation. To utilize early maturation effectively, a simple and reliable in-season measure of maturity is needed. The relation of physiological cutout date (an in-season measurement of maturity) to mean maturity date and % first pick (harvest-based measurements of maturity) has not been established. The objective of this study was to determine whether physiological cutout date provides an accurate in-season measure of maturity.

MATERIALS AND METHODS

Comparisons of physiological cutout date with harvest-based measures of maturity were made using data from three data sets. These data, which evaluated treatments that would likely affect crop maturity, were selected because they included measurements of nodes above white flower, sequential harvests, and yield. The three experiments were established to evaluate: (i) thrips control by aldicarb (2-methyl-2-[methlythio]propionaldehyde *O*-[methylcarbamoyl] oxime) treatments in 1986 and 1988; (ii) effects of N-application rates on different cultivars in 1994; (iii) cultivar performance at three locations of the Arkansas Cotton Variety Test in 1989 and 1990.

Thrips Control Test

Yearly experiments beginning in 1986 at the Cotton Branch Experiment Station near Marianna, Arkansas, were designed to examine both the effects of thrips (*Frankliniella* spp.) and/or tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) infestations on cotton development. This report includes data from 1986 and 1988, two years in which thrips infestations occurred (infestation was more severe in 1986).

Cotton ('Stoneville 506') was planted on 2 May 1986 and 12 May 1988 on a Calloway silt loam (fine-silty, mixed, thermic Glossaquic Fragiudalfs). Plots, replicated three times, were assigned to one of six early-season insecticide schedules. Treatment combinations of aldicarb 15G applied in-furrow and side-dressed at first square are listed in Table 1. The side-dressed applications were to provide control of tarnished plant bugs with little additional control of thrips.

Nodes above white flower counts were made twice (77 and 88 d after planting) in 1986 and four times (69, 77, 82, and 88 d after planting) in 1988. At each sampling time, plants having a first-position white flower were chosen randomly across the six rows within a plot. Average nodes above white flower were determined from 23 to 27 plants/plot in 1986 and 19 to 44 plants/plot in 1988. These data were used to determine days from planting to nodes above white flower = 5.0 (physiological cutout date) for each plot, as described by Bourland et al. (1991). In most cases, physiological cutout date in each plot was calculated by interpolating between two data points; however, when nodes above white flower did not progress beyond 5.0, the decline between the two data points nearest nodes above white flower = 5.0 was used to extrapolate physiological cutout date.

Plots were hand-harvested in 1986 on 10, 17, 27 September and 1, 9 October; and in 1988 on 13, 22, 27 September and 4, 11 October. For each plot, mean maturity date was computed using the formula given by Christides and Harrison (1955). Because the experiments were hand-harvested multiple times, a true % first pick was not attained. For comparison, the earliest sequential harvest that provided at least 60% accumulation of total yield (fourth week of harvest in both 1986 and 1988) was assigned arbitrarily as *first pick*.

Cultivar by N-Rate Test

A long-term N-rate study (with identical, annual treatments of N) was established in 1988 on a Sharkey silty clay soil (very-fine, smectitic, thermic Chromic Epiaquerts) at the Northeast Research and Extension Center, Keiser, Arkansas. Three cotton cultivars ('Tamcot HQ95,' 'Deltapine 20,' and 'Stoneville LA887') having different expected maturity were planted on 12 May 1994 in long-term N-rate plots. Liquid N (32% N) was applied at rates of 0, 56, 112, 168, and 224 kg ha^{-1}. Prior to planting, 56 kg ha^{-1} N was knifed into the side of beds (except for the 0 kg ha^{-1} N treatment). Additional N was applied to the 112, 168 and 224 kg ha^{-1} N plots at early squaring (56 kg ha^{-1} N) and the remainder at early flowering. Nitrogen treatments were arranged in a Latin Square design, with the three cultivars randomized within each N rate. Plots consisted of four rows (1.0-m centers) that were 15 m long.

Weekly nodes above white flower measurements were initiated at approximately first flower and continued until 1 wk after average nodes above white flower = 5.0. Within each of the center two rows of each plot, nodes above white flower were determined from a random sample of five consecutive plants (10 per plot) that had a first-position white flower.

Biweekly sequentially harvested seedcotton weights in a 0.9-m section from an outside row of each plot were used to calculate mean maturity date (Christides and Harrison, 1955). The center two rows of each plot were machine harvested on 7 and 28 October 1994. The percentage of total seedcotton in the first of two harvests was calculated and expressed as % first pick. Gin turnout was determined from boll samples and used to convert seedcotton yield to lint yield.

1989 and 1990 Arkansas Cotton Variety Tests

Data for yield, % first pick, and nodes above white flower data were obtained from the Keiser–irrigated, Keiser–no irrigation, Clarkedale–irrigated, and Rohwer–irrigated sites of the 1989 and 1990 Arkansas Cotton Variety Tests. Methods for determining yield and % first pick data are included in annual variety test publications (Stringer and Bourland, 1990, 1991). Nodes above white flower and physiological cutout date for these tests were reported by Bourland et al. (1991). Two-row plots at each test site measured ≈15 m long on 1.0-m centers and were arranged in a randomized complete block with four replications. Nodes above white flower of 8 to 10 random plants per plot were determined at roughly weekly intervals.

Statistical Analysis

Within each of the above tests, maturity (physiological cutout date, mean maturity date, and % first pick) and yield measurements were evaluated using analysis of variance. The proportion of variance attributed to non-error sources of variation is indicated by R^2 values. Means were separated using Fisher's Protected LSD test at the $P = 0.05$. Pearson's linear correlation coefficients were used to compare the maturity and yield parameters.

RESULTS AND DISCUSSION

Thrips Control Test

Each of the measures of maturity (physiological cutout date, mean maturity date, and % first pick) indicated that earlier maturity is associated with aldicarb treatments (Table 1). Crop maturity tended to be enhanced as the rate of aldicarb application increased and with in-furrow compared with side-dress application.

Variation in physiological cutout date and mean maturity date appeared to be greater in 1986 than in 1988 (Table 1). Maturity delay measured by mean maturity date would be expected to be less than that measured by physiological cutout date, if the delay were to force plants into seasonal cutout. On the basis of historical weather data and with the use of an 85% risk factor, seasonal cutout was determined to occur on 7 August at Marianna (Bourland et al., 1997), which, in this test, is equivalent to 97 days after planting. In 1988, the relative magnitudes of delay were similar for the two measurements.

Cultivar by N-Rate Test

Significant variation was found among cultivars and N rates for each measure of maturity and for lint yield (Table 2). As expected, maturity tended to be delayed and yield increased by the higher N rates. The ranges of variation among N rates were similar for physiological cutout date and mean maturity date; however, the ranges of variation among cultivars differed greatly. These parameters provide measurements of maturity at different times of crop development. Apparently, maturity of cultivars was affected by late-season development

Table 1. Measurements of maturity (physiological cutout and mean maturity dates) and yield associated with in-furrow (IF) and side-dressed (SD) aldicarb treatments at Marianna, AR, in 1986 and 1988.

Year	Treatment IF	Treatment SD	Physiol. cutout	Mean maturity	First pick†	Yield
	-------- kg ha^{-1} --------		d	d	%	kg ha^{-1}
1986	0	0	104	152	62	1051
	0	1.12	106	150	69	1158
	0.56	0	76	144	79	1321
	0.56	0.56	73	140	90	1442
	0.84	0.84	76	142	85	1368
	1.12	0	61	143	82	1340
	LSD 0.05		19	3	10	163
	CV, %		12.7	1.3	7.3	7.0
	R^2		0.82	0.91	0.84	0.80
1988	0	0	89	142	61	1112
	0	1.12	90	141	70	1210
	0.56	0	88	136	80	1508
	0.56	0.56	87	136	81	1373
	0.84	0.84	86	135	83	1305
	1.12	0	87	135	84	1320
	LSD 0.05		1		9	ns
	CV, %		0.9	1.0	6.5	13.1
	R^2		0.86	0.89	0.84	0.50

† First pick was defined by earliest sequential harvest (fourth week of harvest each year) in which all treatments had at least 60% of total harvest.

(after physiological cutout) more so than was maturity associated with N rates.

Correlations of Maturity Measurements and Yield

Significant and consistent correlation coefficients were found among the maturity measurements in the thrips control tests in 1986 and 1988 and in the cultivar by N-rate test in 1994 (Table 3). Earlier maturity was associated with lower values of physiological cutout date and mean maturity date but with higher values of % first pick. Correlations between the two harvest-based measurements, mean maturity date and % first pick, tended to be higher than the correlations with physiological cutout date.

Because they are measured at different times, some variation in the relationships among these maturity parameters should be expected. Sequentially, physiological cutout date would occur first, followed by mean maturity date and % first pick. Because physiological cutout date indicates variation in maturity at physiological cutout, no factor that affects rate of boll opening would be measured. Mean maturity date provides a realized, harvest-based measure of maturity, with precision increasing as the number of harvests (or counts of open bolls) increases. The latest measurement, % first pick, typically occurs after defoliation when 80 to 90% of cotton is open. These data indicate that physiological cutout date is related to established, harvest-based measurements of maturity, and they support the use of physiological cutout date for defining maturity.

As indicated in these tests, the relationship of maturity and yield may vary greatly. Early maturity (as indicated by all three measurements) was associated with higher lint yields in the 1986 thrips-control test, associated with lower yields in the 1984 N-rate test, and not significantly correlated in the 1988 thrips-control test (Table 3).

1989 and 1990 Arkansas Cotton Variety Tests

Two measurements of maturity, physiological cutout date and % first pick, were determined in these variety tests. Bourland et al. (1991) found significant variation in nodes above white flower among cultivars for 35 of 36 date-by-location combinations in the 1989 and 1990 Arkansas Cotton Variety Tests. The one exception was a late-season evaluation in a nonirrigated test where the average nodes above white flower = 3.0. Obviously, in this exception all plants were far beyond physiological cutout, and genetic differences were overwhelmed by the environment and the physiological status of the plants.

Table 2. Yield and maturity measurements in a cotton cultivar response to N rate test at Keiser, Arkansas, in 1994.

Cultivar	N rate kg ha^{-1}	Physiol. cutout d	Mean maturity d	First pick† %	Yield kg ha^{-1}
Tamcot HQ95	0	70.3	129.9	92.8	406
	56	73.1	130.5	93.2	882
	112	77.0	132.3	91.7	1027
	168	75.3	132.1	92.5	993
	224	75.3	134.5	91.8	1070
Deltapine 20	0	71.7	136.4	90.6	611
	56	74.9	136.4	88.1	1199
	112	81.3	142.1	81.4	1437
	168	80.9	142.1	74.4	1576
	224	79.1	143.6	73.7	1555
Stoneville LA887	0	74.5	146.5	84.0	520
	56	79.5	146.3	81.1	1217
	112	85.2	150.2	74.5	1453
	168	88.8	152.5	65.7	1564
	224	88.3	152.6	66.8	1549
LSD 0.05, cultivar X N rate		3.1	ns	4.2	123
Tamcot HQ95		74.2	131.9	92.4	876
Deltapine 20		77.5	140.1	81.7	1276
Stoneville LA887		83.3	149.6	74.4	1261
LSD 0.05, cultivar		1.1	1.9	1.8	46
	0	72.2	137.6	89.2	510
	56	75.8	137.7	87.5	1099
	112	81.2	141.5	82.6	1306
	168	81.6	142.2	77.5	1378
	224	80.9	143.6	77.4	1391
LSD 0.05, N-rate		2.4	3.0	2.6	91
P, N-rate x cultivar		0.001	0.820	0.001	0.001
CV, %		2.5	2.3	3.8	7.0
R^2		0.94	0.92	0.95	0.98

† % first pick, percentage of crop harvested in first of two harvests.

Table 3. Pearson's correlation coefficients among yield and maturity measurements in aldicarb treatment tests (1986 and 1988) and cultivar response to N rate test (1994).

		Correlation coefficients by test			
Variable 1†	Variable 2	1986	1988	1994	All
Physiological cutout	Mean maturity date	0.76**	0.79**	0.70**	0.45**
Physiological cutout	% first pick	-0.70**	-0.67*	-0.86**	-0.68**
Mean maturity date	% first pick	-0.98**	-0.96**	-0.82**	-0.74**
Physiological cutout	Lint yield	-0.74**	-0.31	0.75**	0.35**
Mean maturity date	Lint yield	-0.86**	-0.38	0.54**	0.38**
% first pick	Lint yield	0.84**	0.31	-0.68**	-0.48**

*, ** Correlation coefficients vary significantly from zero at P= 0.01 and 0.001, respectively.
†% first pick, percentage of crop harvested in the first of two harvests.

Physiological cutout date and % first pick were significantly correlated at each location and over all four locations ($r = -0.81$) in 1990 (Table 4). The two parameters were significantly correlated at only one (Rohwer) of the four 1989 locations. Values for % first pick were very high in the two 1989 Keiser locations, thus narrowing the possible range of cultivar differences. In such situations, the relationship of physiological cutout date and % first pick would be expected to decline. The relationship of % first pick and physiological cutout date was probably limited in the 1989 Clarkedale location by varying expression of Verticillium wilt among the cultivars. Because Verticillium wilt is manifested primarily late in the season, after physiological cutout, it is expected to have little effect on physiological cutout date. On the other hand, by causing premature boll opening, it would greatly

Table 4. Parameters associated with maturity and lint yield of cultivars at four locations of the 1989 and 1990 Arkansas Cotton Variety Tests.

Parameter by year	Keiser, irrigated	Keiser, not irrigated	Clarkedale, irrigated	Rohwer, irrigated
1989 (28 cultivars)				
Planting	15 May	15 May	16 May	26 May
Harvest	10, 23 Oct.	10, 23 Oct.	4, 23 Oct.	24 Oct., 2 Nov.
Physiological cutout				
Mean, d	91.0 ± 2.3	81.3 ± 1.1	85.1 ± 1.5	80.0 ± 3.3
Range, d	88.1 - 95.9	79.0 - 83.3	82.6 - 88.5	73.8 - 87.5
Cutout‡				
Physiological	14 Aug.	4 Aug.	9 Aug.	14 Aug.
Seasonal	06 Aug.	06 Aug.	--	20 Aug.
% first pick†				
Mean, %	90.0 ± 2.6	92.6 ± 2.1	75.2 ± 3.8	74.8 ± 4.5
Range, %	85.6 - 94.4	88.7 - 96.5	65.6 - 81.7	65.7 - 83.6
Yield, kg ha^{-1}	1465 ± 126	1156 ± 96	1184 ± 99	826 ± 94
r, physiological cutout				
vs. % first pick	-0.06	-0.04	-0.27	-0.68**
vs. yield	-0.14	-0.36	0.04	-0.44**
1990 (29 cultivars)				
Planting	29 May	29 May	25 May	10 May
Harvest	17, 29 Oct.	17, 29 Oct.	15 Oct. ‡	26 Oct., 7 Nov.
Physiological cutout				
Mean, d	89.0 ± 2.3	75.8 ± 4.4	86.4 ± 5.7	85.7 ± 3.8
Range, d	84.8 - 94.2	68.7 - 80.9	75.7 - 100.8	77.9 - 93.0
Cutout‡				
Physiological	26 Aug.	12 Aug.	22 Aug.	3 Aug.
Seasonal	19 Aug.	19 Aug.	--†	26 Aug.
% first pick†				
Mean, %	63.5 ± 8.1	79.6 ± 7.8	67.0 ± 13.4	70.9 ± 6.4
Range, %	41.5 - 77.0	57.2 - 90.4	35.0 - 85.0	60.0 - 82.1
Yield, kg ha^{-1}	526 ± 147	656 ± 129	1022 ± 133	900 ± 109
r, physiological cutout				
vs. % first pick	-0.52**	-0.72**	-0.67**	-0.85**
vs. yield	-0.59**	-0.52**	-0.09	-0.40*

*, ** Correlation coefficients vary significantly from 0 at P = 0.05 and 0.01, respectively.

† % first pick, percentage of crop harvested in the first of two harvests.

‡ Physiological cutout is the date when average nodes above white flower = 5.0. Seasonal cutout date occurs 850 heat units prior to harvest completion date (see Bourland et al., 1997). Temperature data for Clarkedale were not available; seasonal cutout dates for Clarkedale should be slightly later than those for Keiser.

§ Test was initially planted 8 May; replanted 25 May. It was harvested only once, and % first pick was determined by visual estimates of percentage of open bolls.

increase % first pick of the more sensitive cultivars. Thus, the relationship between the two measures of maturity was probably greatly affected by the timing and severity of Verticillium wilt.

CONCLUSIONS

As cotton plants develop and mature, first position white flowers progressively occur closer to the plant apex, with physiological cutout attained at nodes above white flower = 5.0. Physiological cutout date (days from planting to physiological cutout) was compared to maturity measurements on the basis of end-of-season harvests in tests that evaluated different factors. Besides the two instances in which delayed first harvest limited variation in % first pick, the only case in which physiological cutout date did not accurately reflect crop maturity was the instance when Verticillium wilt induced premature defoliation and boll opening after physiological cutout. In such a case, maturity measurements based on end-of-season harvests may confound differences associated with both plant maturity and plant resistance factors. Thus, maturity measured by physiological cutout date does not include the influence of any late-season (after physiological cutout) factor. Because earliness is determined before the last effective boll population reaches maturity, physiological cutout date can be used effectively to plan and schedule sequential events, such as termination of insecticide applications, defoliation, and harvest. Physiological cutout date provides a reliable temporal measure of maturity that is particularly useful in tests in which multiple harvests are not planned.

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REFERENCES

Anderson, J.M., R.R. Bridge, A.M. Heagler, and G.R.Tupper. 1976. The economic impact of recently developed early-season cotton strains on firm and regional cropping systems and income. p. 98–100. *In* Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 5–7 Jan. 1976. Natl. Cotton Counc. Am., Memphis, TN.

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. Concept for monitoring the growth and development of cotton plants using main-stem node counts. J. Prod. Agric. 5:532–538.

Bourland, F.M., S.J. Stringer, and J.D. Halter. 1991. Maturity of cotton cultivars in Arkansas as determined by nodes above white bloom. p. 560–563. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 6–10 Jan. 1991. Natl. Cotton Counc. Am., Memphis, TN.

Bourland, F.M., D.M. Oosterhuis, N.P. Tugwell, and M.J. Cochran. 1997. Non-computer version of BOLLMAN. Ark. Agric. Exp. Stn. Spec. Rep. 179, Fayetteville, AR.

Christides, B.G., and G.J. Harrison. 1955. Cotton growing problems. McGraw-Hill, New York.

Oosterhuis, D.M., F.M. Bourland, and N.P. Tugwell. 1992. Basis for the nodes above white flower cotton monitoring system. Arkansas Farm Res. 41(5):3–5.

Oosterhuis, D.M., F.M. Bourland, N.P. Tugwell, and M.J. Cochran. 1996. Terminology and concepts related to the COTMAN crop monitoring system. Ark. Agric. Exp. Stn. Spec. Rep. 174, Fayetteville, AR.

Richmond, T.R., and S.R.H. Radwan. 1962. Comparative study of seven methods of measuring earliness of crop maturity in cotton. Crop Sci. 2:397–400.

Richmond, T.R., and L.L. Ray. 1966. Product-quantity measures of earliness of crop maturity in cotton. Crop Sci. 6:235–239.

Stringer, S.J., and F.M. Bourland. 1990. Arkansas cotton variety and strain tests 1989. Ark. Agric. Exp. Stn. Res. Ser. 403, Fayetteville, AR.

Stringer, S.J., and F.M. Bourland. 1991. Arkansas cotton variety and strain tests 1990. Ark. Agric. Exp. Stn. Res. Ser. 414, Fayetteville, AR.

Waddle, B.A. 1974. Using mid-summer measurements as earliness indicators. p. 78–79. *In* Proc. Beltwide Cotton Prod. Res. Conf., Dallas, TX. 7–9 Jan. 1974. Natl. Cotton Counc. Am., Memphis, TN.