AGRONOMIC FACTORS AND YIELD VARIABILITY

William R. Meredith, Jr.
USDA, ARS, CP&G
Stoneville, MS

Abstract

A review of some agronomic factors that influence yield is given. Yield is determined through the effects of its yield components: number of bolls/acre, average boll weight, and lint percentage. The 1995 yields in Mississippi were about 80% of their 15-year average. In one comparative study, number of bolls was less than in 1994 by 35% and boll size was about 65% lower than in 1994. Excessive use of Nitrogen (N) on strong land may be one cause of yield instability in the Mississippi Delta. Excessive N rates result in greater vegetative development, delayed maturity and reduced income. The use of Mepiquat Chloride (MC) as a growth regulator has resulted in both positive and negative yield responses. MC reduces the plant height and vegetative growth. Positive response to MC occurs mostly on strong land, when high rates of N and irrigation are used. The optimum planting date in the Mississippi Delta falls between April 20 and May 10. Plantings earlier than April 20 frequently result in poor stands. Plantings later than May 10 generally result in reduced yields and increased vulnerability to insects and bad weather. When crop terminators are applied to bolls 36 days old or younger, or that have less than 600 DD60s of development, both the boll weight and the micronaire are reduced. This review emphasizes that the management decisions in the use of these factors requires proper timing in their use and consideration of the plants' growth and development.

Introduction

Economists tell us that the single most important criteria for profitable cotton production are high yields. The number of factors influencing yield is so large that books could be written on the subject. Most of the presentations at this conference will focus directly or indirectly on yield. Therefore, in this brief review, only a few selected agronomic factors can be discussed. In general, these factors will be those whose economic effects are large and in which differences of opinions often exist on the correct course of action to be taken. These factors involve decisions on soils, nitrogen, potassium, planting date, growth regulators, crop termination, varieties and important interactions. A longer, but still abbreviated, list is given in Table 1.

First, a basic review of cotton growth in the Midsouth is given: Cotton planting is centered around May 1, first pinhead squares are evident in the first week of June, and peak flowering begins in early July. About 85% of the harvestable bolls are set in July. Flower set in early July is about 90% and falls steadily to less than 20% by July 31. Generally, the best weather conditions for cotton growth and fruiting is the six-week period beginning in late June and ending the first week of August. It's been evident in many studies that cotton production should be based on keeping the July flowering and boll retention as healthy as possible. For example, in Figure 1, data derived from a Jenkins and McCarty (1995) study, shows about 90% of the harvestable bolls of their crop came from July flowers. The factors influencing yield do this first by their effects on the components of yield. The yield components of cotton can be written as:

$$Y = N_b \times B_w \times L_p$$

where: Y = lint yield/acre
N_b = number of bolls/acre
B_w = average boll weight
L_p = lint %

These components can be further divided into subcomponents, such as seed/boll, lint/seed, number of seed/acre, and even fiber properties such as length and micronaire. A current example involving variety tests is given to show how yield is influenced by its components. The results in Table 2 with one variety, Sure Grow 125® grown in 1994 and 1995 in 27 comparable test sites (data from Bridge, unpublished data, 1995). The yield in 1995 was 79% of that obtained in 1994. The product of N_b, B_w, and L_p is 79% (0.92 x 0.85 x 1.01 = 0.79). In this study, 35% of the decreased yield in 1995 was due to fewer bolls and about 65% was due to smaller bolls. Further, a breakdown of yield sub-components would show that there was less lint per seed in 1995 than in 1994. The average Mississippi yield was about 20% less in 1995 than that for the last 15 years and smaller bolls was definitely a factor. Any agronomic factor impacting yield will be through the components of yield.

Soils. Differences in yielding ability of the various soil types have long been known. In the Delta (alluvial plain) of the Mississippi River, soils were formed by river deposits left from floods. The heavier soil particles, sand and silt, are deposited first, closest to the rivers and streams, and are followed by the finer particles, clays, deposited further from major waterways. Since the rivers and streams meander over time throughout the Delta, a single cotton field can have many soil types. Along the banks of Deer Creek in Stoneville, it's not unusual to find a Bosket fine, sandy loam, then 150 feet away, encounter a Sharkey clay soil type. The differences in major soil types in such a small area make for challenging management decisions.

Law of the minimum. One very old principle used in plant nutrition studies is the "Law of the minimum" as put

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:180-184 (1996)
National Cotton Council, Memphis TN

forth by Justus Von Leibig in about 1840. His thesis is shown with a barrel made up of many staves (factors). The barrel will hold only as much water (yield) as the lowest stave will allow. The drawing in Figure 2 can be translated . . . The yield of the barrel can hold only 50% of the proposed maximum because only 50% of the CO_2 needed for maximum yield is present. CO_2 enrichment studies such as by Krizek (1986) show that CO_2 is a limiting factor in cotton production. This example was also deliberate to show that despite how much nitrogen (N) is applied, no yield increase will occur while another essential factor is limiting the yield.

<u>Nitrogen</u>. One of the most misused agronomic factors involved in the Mississippi Delta is in applying too much N. Figure 3 shows results taken from a recent study by Boquet et al. (1994) in which N yields increased up to about 100 lbs. N/acre, then leveled off, and finally yields decreased by the 150 lbs. N/acre rate. Similar results from a four-year study by Welch and Eblehar (1996), are being reported at this conference. Their results, summarized in Table 3, showed N increasing the yield to 150 lbs N/acre, then decreasing at the 180 lbs N/acre rate.

Research by both Boquet et al. (1994), and Welch and Eblehar (1996), goes further than the Law of the Minimum, in that additional increments of a yield factor, above the amount needed, can result in decreased yield. Both of the cited studies also show excessive N rates make the crop mature about three days later. Since the average number of days fit for harvest in the Mississippi Delta is about 22 (Cook et al. 1991), the loss of 14% of the harvest season, and decreased yields represents a sizeable economic problem for the grower. The presentation of these two studies isn't meant to suggest actual N rates to be used. Fertility recommendations should be carried out by tailoring the N recommendation to the specific soil and crop conditions, and after proper soil testing.

Part of the yield problem in the Mississippi Delta may be due to application of too much N. Some detrimental effects of too much N are presented in Table 4.

<u>Plant populations</u>. Many studies have shown the basic yield response expected from varying the number of plants/acre. Increasing plant numbers until an optimum leaf area index of about four is reached, is the desired objective for most cotton environments. Further increases in plant numbers above that needed to achieve maximum light interception will result in decreased yields. The reason for this is that in high population densities, many plants produce no bolls and are acting as weeds. The general optimum for maximum yield in the Midsouth is a range of 35,000 to 50,000 plants/acre.

<u>Planting date</u>. The results in Figure 4 show a generalized yield response to planting date in the Mississippi Delta. The data came from five studies and have been normalized using the May 1-3 (a common planting date in all studies) as the normalizing parameter. The results show a broad window of optimum planting date for yield of about three weeks. This period from April 20 to May 10 of course varies with years and weather. With the improvement in planting seed quality and new improved seed treatments more growers are gambling on planting earlier than April 20. However, the data suggests that no advantage in yield and earliness is achieved by this practice. A general thumb-rule at Stoneville, is to begin planting on the first date after April 19 that we have a <u>favorable weather forecast</u>.

<u>Irrigation</u>. It's well known that water can be a limiting factor for high yields. The maximum water needs of the crop are during the maximum fruiting and boll maturation stage of crop development. This period coincides with the hottest weather and therefore more water is needed to keep the plants' cooling system operating efficiently. As indicated, timing the water to be present at the desired plant growth stage is the key to good irrigation management. In the Midsouth, due to natural precipitation not being predictable, there are many instances where too much water and poor timing of irrigation occurs. It is believed by many growers that late season irrigation helps fill-out the developing bolls. I'm not aware of any data that shows late season irrigation increases boll size. It is more likely that late season irrigation results in more boll rot, increased vegetative growth, a haven for insect pests, delayed maturity, decreased grades, and more difficult harvesting.

<u>Growth regulators</u>. One of the factors in which varying yield results are frequently obtained, is the use of growth regulators. The most used growth regulator is Mepiquat Chloride (MC), which common trade name is PIX®. It is the interaction of MC with plant development that results in the varying results. The results in Figure 5 are from research at Stoneville by Tupper et al. (1995). The data show a healthy yield response to potash. However, the use of MC did not result in any further yield increase and the higher rate of MC decreased yields, therefore a negative yield interaction. In contrast, research at Stoneville with N and MC, reported by Welch and Eblehar (1996) at this conference shows a positive N x MC interaction. Their results, given in Figure 6, show MC had little effect on yield at the 90 and 120 lbs. N/acre rates, but increased yields significantly by 55 and 59 lbs. lint/acre at the 150 and 180 lbs. N/acre rates. Also, interactions with planting dates and MC have been shown by Cathey and Meredith (1988). Their results are summarized in Table 5. MC significantly decreased lint yields of the early planting (April 15) by 55 lbs. lint/acre. MC on the May 1 and 15 plantings resulted in increases of 67 and 121 lbs. lint/acre, respectively. In the two later plantings, MC also resulted in the crop being earlier for defoliation by one day. Plant height data taken in August shows that delayed plantings result in a taller crop (Table 4). Height in this study is a measure of vegetative growth. It's evident in Table 5 that MC decreased vegetative growth and increased reproductive growth in the May 1 and 15 plantings. Some varying yields results with MC are related to the varying growth conditions of the crop. On strong land or under management regimes where high N rates are applied, late season irrigation is used, or late plantings occur, MC may give the grower an economic response. While I'm not aware of any definitive data, late maturing varieties may respond more to MC than early maturing varieties.

Variety x environment interaction. There is no single variety best suited for all situations. Porter et al. (1995) showed (Figure 7) a planting date x variety interaction for 'Deltapine 5415' and 'DES119'. When planted early, the late maturing variety Deltapine 5415 was the higher yielder. When planted late, DES119 had the higher yield. An interaction of years and varieties is indicated in Figure 8. Each of the three years, a different variety was the highest yielding variety. The cause for the interaction isn't known but maturity and varying growing conditions between years probably are involved in the interactions.

Crop termination. One of the more complicated decisions for the grower is when to apply crop defoliants and terminators. Several general thumb-rules are available, such as "defoliate when 65% of the crop is open".

Crop terminators are just as their name indicates, they terminate any further crop development. How much yield is lost by crop termination is dependent on how many immature bolls are present. The response curve in Figure 9 shows how the effect of Prep® on bolls of different ages influences their yield. Bolls that are 36 days of age or older (or DD60s = 600) after flowering lose no yield since they have completed the maturation process. Premature crop termination not only results in lower yields but also results in low micronaire and an increase in neps and short fiber content.

Conclusion

This review emphasizes that the management decisions in the use of these factors requires proper timing in their use and consideration of the plants' growth and development.

Table 1. Agronomic factors which influence cotton yield.

FACTORS	FACTORS
Soils	Plant populations
Varieties	a. row spacing
Fertilization	b. plant numbers
a. nutrients	Irrigation
b. method of application	Growth regulators
Planting date	Crop termination
Weed control	Harvesting
Stand establishment	Ginning

Table 2. Average Sure Grow 125 yields in 1994 and 1995 from 27 comparative tests (Data source Bridge, 1995).

Year	Lint Yield/ Acre	Boll No. Linear Ft.	Boll Wt. (G)	Lint %
1994	1304	20.9	5.86	36.9
1995	1035	19.3	4.97	37.1
% of 94	79	92	85	101

Table 3. Effect of Nitrogen on average lint yields and percent first harvest from 4 years study (1992-1995). Reference: Welch and Eblehar (1996).

Nitrogen Rate/Acre	Lint/ Acre	% First Harvest
90	980	92.7
120	1028	92.0
150	1048	91.2
180	1023	90.8
LSD 0.05	20	1.2

Table 4. Detrimental effects of too much Nitrogen.

1	Excessive vegetative growth	8	Increased diseases
2	Delayed maturity	9	Increased insects
3	Regrowth	10	Reduced micronaire
4	Poor defoliation	11	More trash & ginning
5	Poor harvesting conditions	12	Reduced grades
6	N in ground water	13	Reduced yields
7	Leaching of K, Ca, Na, & Mg	14	Reduced profits

Table 5. Effect of PIX® and planting date on yield, earliness, and plant height (Cathey and Meredith, 1988).

Plant	Total lint/acre		% First Harvest		Plant Height (ft)	
Date	PIX	Check	PIX	Check	PIX	Check
Early-Apr 15	1162	1217	60.2	59.2	3.9	4.2
Opt-May 1	1301	1234	64.5	62.1	3.9	4.7
Late-May 15	1067	946	63.7	60.2	4.2	5.1
LSD 0.05 (PIX vs. Check)	55		2.4		0.4	

References

1. Boquet, D.J., E.B. Moser, and G.A. Breitenbeck. 1994. Boll weight and within-plant yield distribution in field-grown cotton given different levels of nitrogen. Crop Sci. 86:20-26.

2. Cathey, G.W. and W.R. Meredith, Jr. 1988. Cotton response to planting date and Mepiquat Chloride. Agronomy J., 80:463-466.

3. Cook, F.T., D.W. Parven, Jr., and S.R. Spurlock. 1991. The costs of cotton harvesting systems in the Mississippi Delta. MS Agr. & For. Exp. Stat. Bulletin 972. 9 pp.

4. Jenkins, J.N., and J.C. McCarty. 1995. Useful tools in managing cotton production: End of season plant maps. Mississippi Agr. & For. Experiment Station Tech. Bull. 1024, 21 pp.

5. Krizek, D.L. 1986. Photosynthesis, dry matter production and growth in CO_2 enriched atmospheres. In J.R. Mauney and J.M. Stewart (eds.) Cotton Physiology, pp. 193-224. The Cotton Foundation. Memphis, TN.

6. Porter, P.M., M.J. Sullivan, and L.H. Harvey. 1995. Cotton variety by planting date interaction in the Southwest. In J.H. Herber (ed.) Proc. Beltwide Cotton Prod. Res. Conf., January 4-7, 1995, San Antonio, TX, pp. 516-521. Natl. Cotton Council of Am., Memphis, TN.

7. Tupper, G.R., C.E. Snipes, and M.W. Eblehar. 1995. Effect of varying PIX and potassium levels on non-irrigated cotton lint yield. In H.J. Herbert (ed.) 1995 Proc. Beltwide Cotton Prod. Res. Conf., January 4-7, 1995, San Antonio, TX, pp. 1331-1332. Natl. Cotton Council of Am., Memphis, TN.

8. Welch, R.R. and M.W. Eblehar. 1996. Evaluation of Plant growth regulators with varying nitrogen management. In H.J. Herbert (ed.) 1996 Proc. Beltwide Cotton Prod. Res. Conf., January 8-12, 1996, Nashville, TN. Natl. Cotton Council of Am., Memphis, TN. (In press)

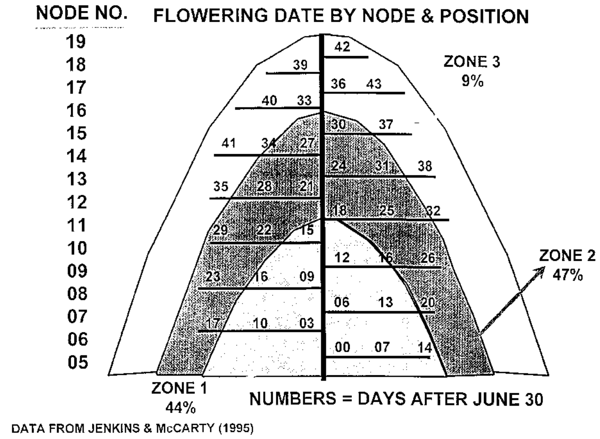

Figure 1. Approximate flowering date, days after July 30 indicating zones where DES 119's two-year yield was.

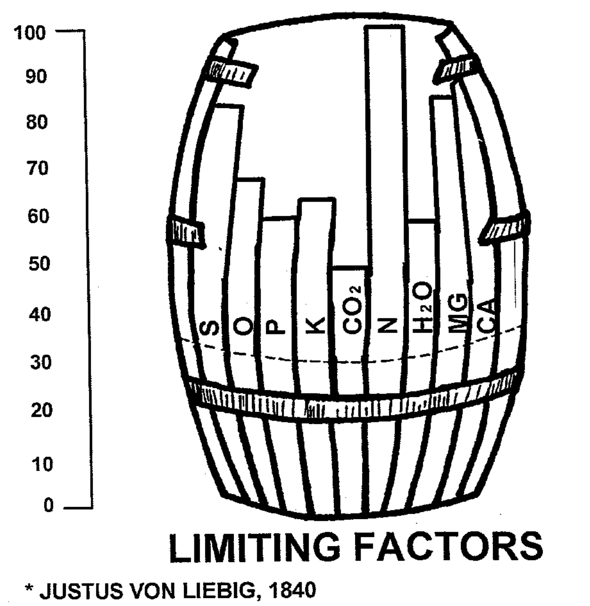

Figure 2. Justus Von Lleibig's law of the minimum example on limiting factors influence on yield.

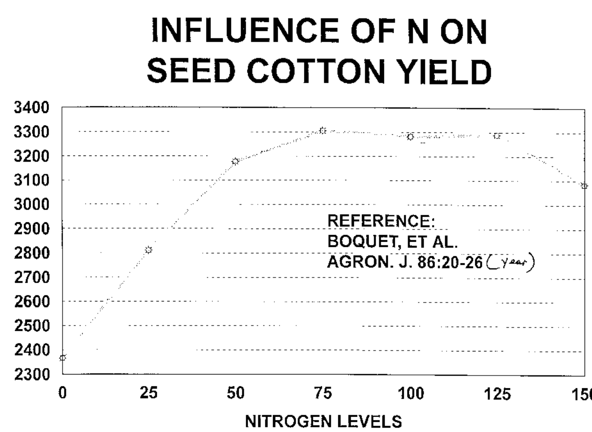

Figure 3. Influence of nitrogen on seed cotton yield.

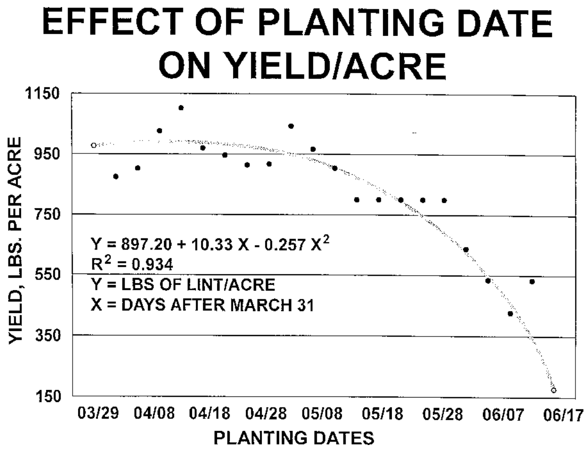

Figure 4. Effect of planting date on yield at Stoneville, MS.

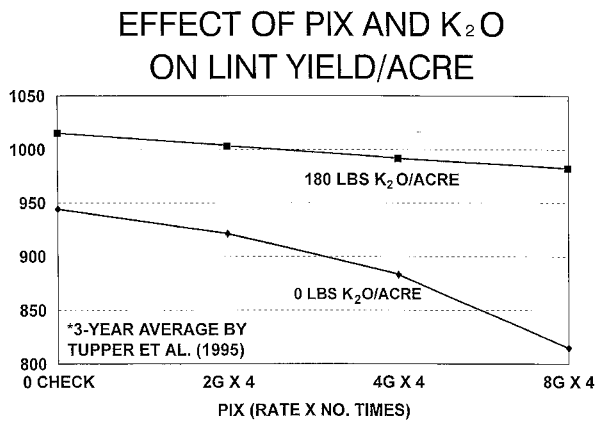

Figure 5. Effect of PIX and K_20 on lint yield.

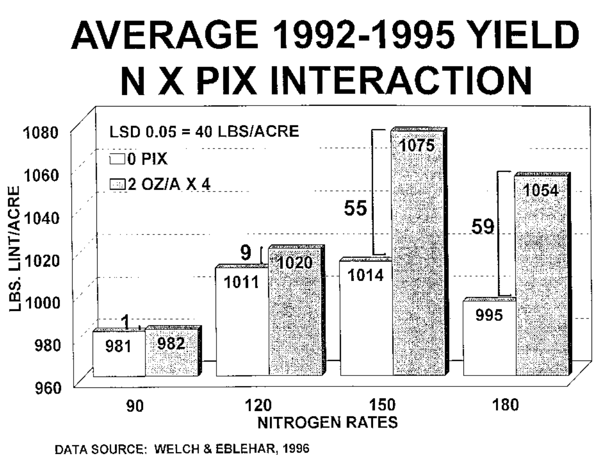

Figure 6. Effect of nitrogen and PIX on yield at Stoneville, MS.

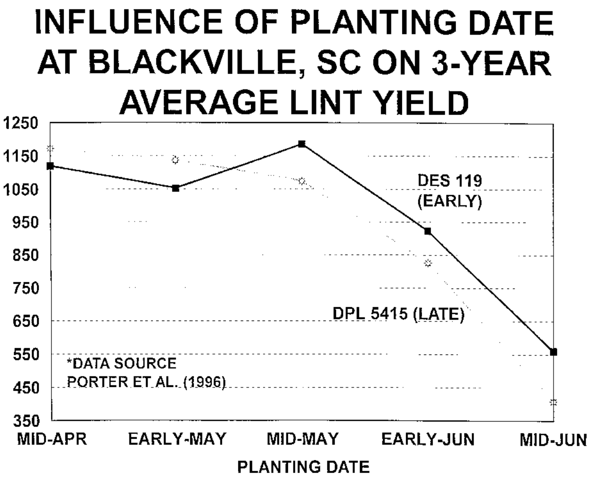

Figure 7. Influence of planting date and variety on lint yields.

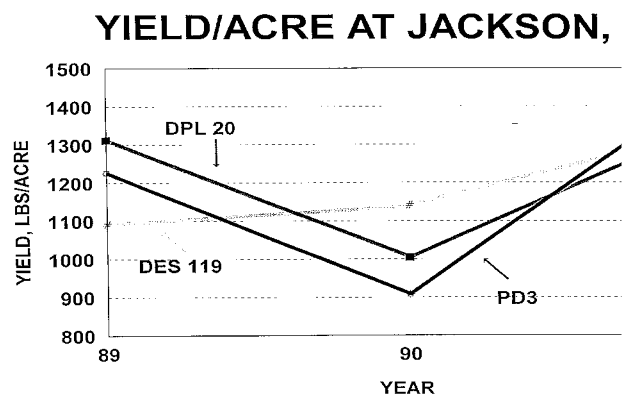

Figure 8. Variety x year interaction at Jackson, TN.

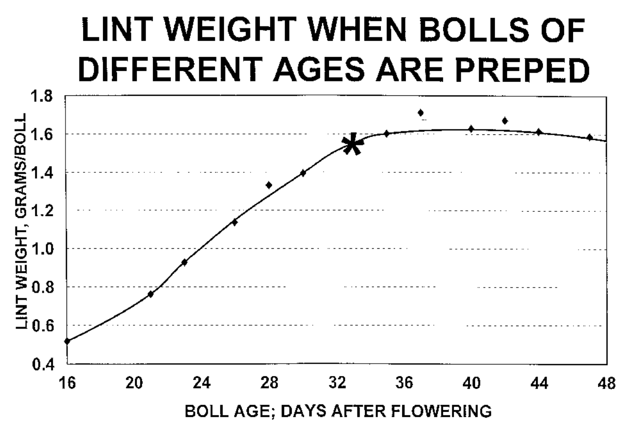

Figure 9. Lint weight/boll as influenced by the bolls age when Prep® was applied.