DISEASES AND NEMATODES: THEIR ROLE IN COTTON YIELD STAGNATION – SUMMARY OF A BELTWIDE SPECIAL SYMPOSIUM

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Cotton Yield Trends

Yields are affected by genetics, environment and management. When cotton prices are low, producers tend to skimp on the latter. Environment can also alter pest pressure. For example, annual yields in Mississippi are inversely correlated with mean daily temperatures in July and August, the principal period of fruit set and boll maturation. One rationale would ascribe this correlation to heat stress, and the probable association of low rainfall with high temperatures. However, such trends are invariably confounded by the biology of the major pests that are infesting cotton during the same periods. For example the life cycles of insect pests are accelerated by temperature, and high temperatures magnify moisture stress when root systems have been compromised by nematodes and diseases, as was frequently observed in 1999 and 2000.

During the period of the 1990's major commercial cotton planting seed companies emphasized development of transgenic varieties with proprietary pest-managing traits. Based on their pest management efficacy, the transgenic varieties have increased their collective market share from no presence in 1994 to about 78% in 2001. However, these transgenic varieties were derived from transformed 'Coker 312', an obsolete variety that is amenable to tissue culture. The transformed lines were then backcrossed with varieties that were top-yielding in the early 1990's, when such selections for backcross parents were the best available. Several generations were needed to produce agronomically acceptable transgenic varieties for commercial release. As a consequence of the time needed for variety development, the yields of the current transgenic varieties are comparable to those of the parent varieties that were originally developed about 10 years ago. Similar trends in the relation of yields of transgenic soybean varieties to those of currently developed non-transgenic soybean varieties have been observed. In general the results of breeding programs tend to reflect the breeding objectives. When emphasis is again placed on increasing yields, it is probable that yield potential of newly released varieties will again increase.

Cotton Diseases

Full yield potential may be achieved only with favorable weather, good agronomic management, and minimization of losses due to pests, either through infrequent or low infestations of the pests, host plant resistance against the pests in the cultivated varieties, avoidance of pests by means of cultural practices, or effective exogenous means of pest management. Plant diseases and nematodes have long been recognized as causing yield losses, but have not been evaluated in relation to the apparent post 1990 yield stagnation. Major diseases of cotton with Beltwide economic significance include *Pythium spp*. and *Rhizoctonia solani,* which cause seedling diseases that affect stands and root development; systemic wilts, including Verticillium wilt caused by *Verticillium dahliae* and Fusarium wilt caused by *Fusarium oxysporum* f. sp. *vasinfectum*; bacterial leaf blight caused by *Xanthomonas campestris pv. malvacearum*; soil-borne root rots, such as black root rot, caused by *Thielaviopsis basicola*, boll rots, caused by as many as 170 fungal species, many being secondary saprophytes, and nematodes, with three species being especially damaging, the root-knot nematode (*Meloidogyne incognita*), the reniform nematode (*Rotylenchulus reniformis*), and the Columbia lance nematode (*Haplolaimus columbus*). In addition, in recent years, two previously unnoted diseases, whose etiologies have not yet been described, have been observed. These are seed rot that has been found to cause economic damage in South Carolina and the Gulf Coastal Region of South Texas (Jones et al. 2000), and Bronze wilt that has recently been described (Bell et al., 2002). The latter was observed as early as 1995 in the U.S. in specific varieties, and in some instances was associated with major economic losses.

Impact of Cotton Diseases

Disease loss estimates are ultimately based on observations from small-plot research, wherein specific practices, cultivars, or crop protection chemicals (chiefly fungicides and nematicides) are applied as treatments and the effects measured. The data from small-plot tests may be considered as a whole, and correlations made between the relative incidence of the disease and its effects on plant growth and yields. Pathologist, nematologists, or other crop specialists then use the disease impact measurements from small-plot observations to estimate the impact of a disease in a specific field situation as a function of its observed severity. Regional and national disease loss estimates are attempts to integrate effects over geographic areas.

Clearly such estimates are imperfect. These estimates are further flawed when chemical treatments studies, designed to treat one pest such as nematodes, fail to consider the effect they have on other pathogens or beneficial organisms in the soil. To discern the role of diseases and nematodes in yield stagnation, better methods for estimating yield losses must be developed.

In previous decades, wilts and bacterial blight were common and damaging diseases in the U.S. and other cotton crops. Economic damage from these diseases has now been greatly reduced by development of resistant varieties and cultural control practices (Blasingame and Patel, 2001; El-Zik, 2002).

Seedling diseases are endemic throughout the Cotton Belt, but are most troublesome in the northern areas of the Belt, because such locations typically experience more frequent and longer periods of sub-optimal soil and air temperatures for cotton seedling growth than do more southern areas. The great majority of cottonseed is treated with two different types of fungicides, and some planting seed is treated again either by hopper box treatment or by application of fungicide directly into the planted furrow. In spite of such measures, yield losses to seedling diseases persist.

Disease loss estimates show a significant rise in losses due to nematodes. In Arkansas losses are especially severe in fields infected with both the root-knot nematode and *Thielaviopsis basicola* (Kirkpatrick et al., 2002). A similar correlation of high losses and the simultaneous occurrence of root-knot nematode and *T. basicola* is reported in the Texas High Plains (Wheeler, 2002). The two pathogens occur together on approximately 30% of the irrigated acreage in West Texas. The pest whose range is most rapidly expanding in U.S. cotton is the reniform nematode. The reniform nematode is a tropical species that was first reported in the U.S. in recent decades. It now infests most of the Southeast and is moving northward in the Mid-South, being first reported in Tennessee in 2000. The reniform nematode is now estimated to infest more than 60% of the cotton acreage in Mississippi. Reniform nematodes are typically found in high populations throughout affected fields, and yield losses of 150-200 lbs. lint/acre are common in heavily infested fields.

Bronze wilt is a newly described disease that can cause extensive damage when night temperatures remain at or above 25^{o}C (Bell, 2002). The disease is generally recognized by bronzing of leaves in the upper portion of the plant. The foliar symptoms are believed to be due to loss of secondary root mass. Similar symptoms have been described in other cotton growing countries (Raj, 1991). In the U.S., devastating losses due to bronze wilt have been associated with specific varieties. However, greenhouse and growth chamber studies indicate that most current commercial varieties suffer yield losses due to this disease, with a strong correlation between yield loss and earliness (Bell, 2002).

Boll rot losses vary significantly from year to year. Major losses occur when rainfall and humidity are high during the period of boll opening. However, cotton bolls are continuously susceptible to boll rot fungi, particularly following mechanical damage or insect feeding. Harvest inefficiencies due to hard lock are endemic in the South Atlantic and Gulf Coastal regions. Hard lock may occur because the cotton is simply too immature to open, or it may be caused by rainfall at the time of boll opening. In the latter case several saprophytic fungi may be involved.

Review of the disease loss estimates suggests that losses from Bacterial leaf blight and Verticillium wilt are declining because of the development and use of resistant varieties. Losses from seedling diseases are variable but the trend is relatively constant. Losses to boll rot are highly variable among years, but like seedling diseases, there is no positive or negative trend. In contrast, estimates of losses due to nematodes, particularly the reniform nematode, are increasing. The black root pathogen is more commonly found in certain areas of the Mid-South (Kirkpatrick, 2002). Bronze wilt and seed rot, as described in South Carolina are new diseases.

Yields and Diseases in Australian Cotton

Cotton yield stagnation appears to be a worldwide phenomenon over the past decade. The one exception is Australia. In Australia, extensive cotton culture began only in the last century, and Australia has generally recorded steady increases in cotton yields through the present. The low yields in Australia in recent years may be accounted for by unfavorable weather (Allen, 2002). However, the trends in relative occurrence of disease inocula in Australian soils are similar to those found in the U.S. With the introduction of varieties with resistance to Verticillium wilt and Bacterial blight, inocula of these disease-causing organisms are less frequently found in Australia's cotton soils; however, as in the U.S. the prevalence of *Thielaviopsis basicola* appears to be increasing. Since Australia has a shorter history of cotton culture than other cotton producing areas, it will be interesting to note if a trend toward yield stagnation appears in Australia over the next several years as the pest biota that exploits cotton becomes more established.

Summary

During each period of yield stagnation, pessimists have argued that cotton has reached it full yield potential and there will be little more progress. Periods in which such arguments are heard, have repeatedly been followed by periods of yield increases. Thus, there is probably no inordinate cause for concern about the possibility for future yield improvement. One reason advanced to explain why U.S. cotton yields have not increased in recent years is the narrow genetic base of major U.S. cotton varieties. If true, then incorporating new material into breeding programs is a worthy objective for public research institutions.

To pull ourselves out of the current stagnation trend, two strategies are called for: 1) achieving improved yields with stronger varieties, and 2) removing barriers that limit yield. Diseases and nematodes represent one such barrier. Disease loss estimates indicate the reniform nematode is a new and important component of this barrier. This is due to reniform's widening range and increasing population density. Resistance to this nematode is not available and its interaction with other pathogens is largely unknown. Economical non-chemical approaches to overcome this yield impediment must be developed. This calls for variety improvement in concert with host-plant resistance and an improved comprehension of reniform/pathogen interactions.

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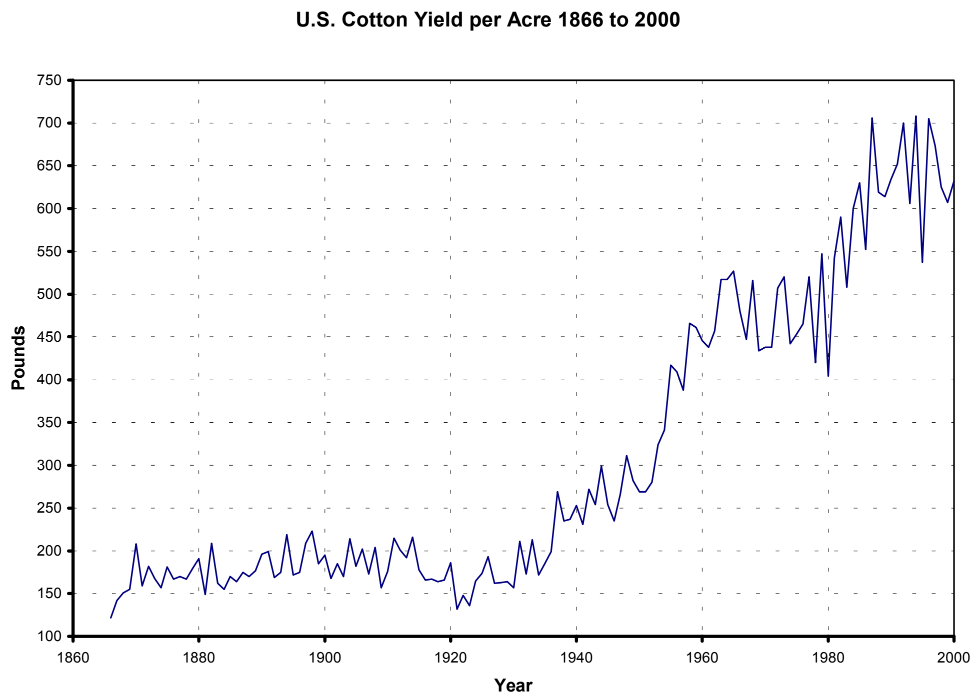

Figure 1. Long-term U.S. Cotton Yield Trend.