2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

LATE SEASON FOLIAR DECLINE IN SAN JOAQUIN VALLEY COTTON: NUTRIENT INTERACTIONS

R. B. Hutmacher and R. N. Vargas
University of California
Shafter, CA
Steve D. Wright
University of California Cooperative Extension
Tulare, CA
G. Stuart Pettygrove
University of California
Davis, CA
B. A. Roberts
UCCE - Kings County
Hanford, CA
Joe Fabry
Fresno, CA
Herman Meister
UC Coop Ext - Imperial Co,
Holtville, CA

Abstract

Observations of various severities of a late season foliar decline have increased in number in Acala (*Gossypium hirsutum* L.) and Pima *(Gossypium barbadense* L.) fields in California in recent years. These problems so far have defied a good description in terms of causes. A recurring problem seen in numerous locations in prior years, and even more widespread in 2004, was a collection of mid- to late-season crop symptoms that have been referred to by a variety of names, including “foliar decline”, “foliar or late-season collapse”, “bronzing” among others. Symptoms are somewhat varied, and can be as minor as a late season "bronzing" or “reddening” of the upper plant foliage, including reddening of petioles and upper stems of the plant near the newest main-stem meristematic growth. When these effects come about relatively late in the season, after most of the harvestable bolls have been set and lint maturity is quite far along, effects on yield or fiber quality have typically been minor. If the symptoms, and particularly the leaf loss and cessation of terminal meristem growth occur earlier, fiber quality can be impacted in developing bolls, and yields can be reduced due to loss of additional fruiting sites and reduced photosynthetic leaf area to meet boll carbohydrate needs. Observations from a large number of visits to fields with some expression of these symptoms are summarized in this paper. Information collected to date shows that while in many cases these symptoms are a good fit for potassium deficiency, in many of the fields where data is presented here, symptoms are not associated simply with low soil exchangeable potassium. A number of hypothesis for some causal factors and areas for future research are reviewed.

Field Observations, Measured Impacts

It is important to state that the broad classification of a “syndrome” or problem described here as a leaf decline is likely to include a collection of plant problems that represent a range of field situations, with one or more primary and secondary causes likely involved. In many fields that could be described as having some variation of foliar decline in recent years, a mix of observations and findings apply, including the following:

- Symptoms vary widely in severity and timing of first occurrence, even in the same field
- In some fields, evidence of Verticillium as foliar injury and vascular staining is very evident and has been confirmed by tissue / pathogen analyses – however, in many fields, there has been no conclusive evidence of Verticillium.- Verticillium is likely part of what is observed in some, but definitely not all locations investigated for late-season decline symptoms
- Verticillium incidence in these fields has been highly variable with variety, areas of the field and environmental and cultural conditions

- Leaf damage from other pathogens (such as leaf spotting due to *Alternaria*) has often been seen as leaves decline (change color to red or bronze), but UC Pathologists have described these as secondary pathogens causing some damage, but not a primary cause of initiation of the symptoms and decline
- Many of the worst affected areas have been those with a heavy fruit set for the size of the plant and leaf area. This should not be interpreted as indicating this only occurs with large, very high yield plants. Rather, observed problems have been most severe in a wide range of plant sizes with high total boll weight per unit of leaf area remaining on the plant.

Since 1997 in Pima and 2002 in Acala cotton, fields have been evaluated for relative timing, degree of damage in fields where symptoms fit into these broad classifications of "late-season foliar decline". A range of these foliar symptoms have developed and been evaluated in fields in Kern, Kings, Madera and Tulare Counties, and a few fields in Merced and Fresno County with mild but similar symptoms. Depending upon the year and crop conditions, the timing of the damage to foliage and meristems varied from as early as mid-July to as late as mid-September. With a long growing season and a greater number of total bolls needed to achieve high yields in longer maturing Pima and Acala varieties, yields were significantly reduced and components of lint quality affected in many fields where the foliar symptoms occurred starting as early as peak bloom, continuing into fairly severe symptoms and leaf loss greater than 25 percent of total leaf area within the first 2 to 3 weeks after vegetative cutout. In estimates we made in 2002 and 2004, fields with moderate to severe symptoms developing as early as late July to early August had yield losses ranging from about 15 to over 35 percent, with few bolls set after the 16th main stem node in these early-affected plants. Figure 1 shows some first position fruit retention comparisons between fields with and without foliar decline symptoms, indicating both reduced fruit retention and earlier cessation of fruiting branch growth with decline symptoms.

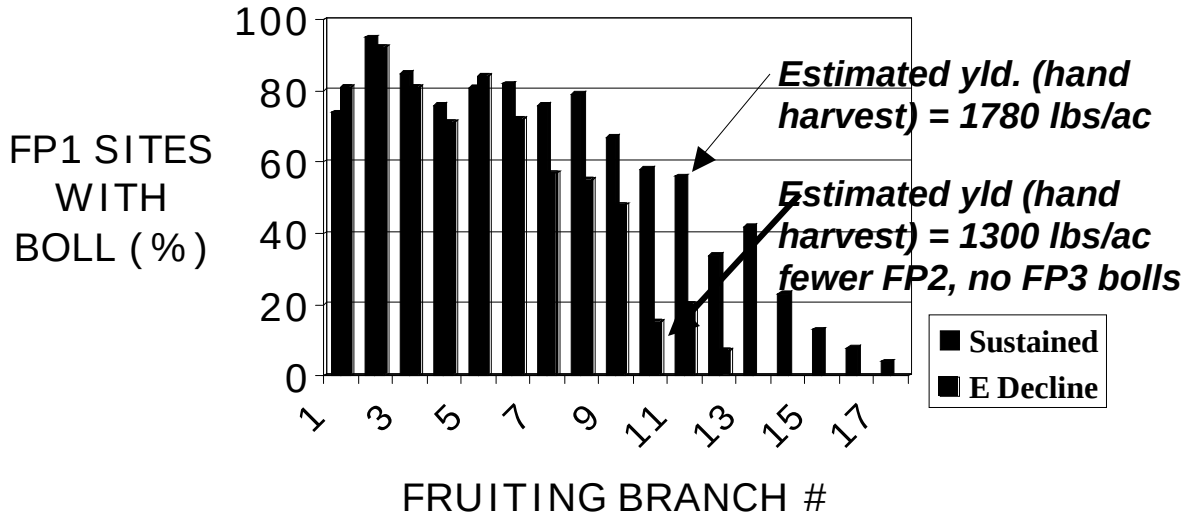

Figure 1. Fruiting patterns (first position on fruiting branch (FP1) site only) described as fruit retention percent as a function of fruiting branch number in Acala cotton fields in 2004. The two fields represented either had (a) sustained growth (Sustained) with no early foliar decline symptoms evident through mid-September, or (b) had significant early foliar decline symptoms (E Decline) as described in this paper. Estimated yields from hand harvests of 13.33 feet of row in the areas of the field that were mapped are shown (1300 lbs in Early Decline areas, 1780 lbs/acre in sustained growth areas of the fields).

Soil and plant tissue nutrient samples were collected for evaluation in over 90 fields showing plant symptoms corresponding with described late-season foliar decline problems, both Pima and Acala. Potassium deficiency has been implicated in some but not all of these fields. This was not necessarily surprising, since "bronzing" and some

of the foliar decline and early leaf loss problems are also symptoms of severe potassium deficiency. Over 90 percent of the fields tested showed low leaf and petiole potassium levels in August and September, but they also showed low N, P and Zn levels. Soil test K and P levels in the 5-15 inch and 15-25 inch zones in affected fields ranged from borderline deficient to sufficient (according to University of California guidelines). Soil test data does not suggest a clear linkage of the "early decline" symptoms with deficient soil potassium levels, although in some cases low soil K is likely a major contributor to the symptoms seen in plants. Figure 2 shows severity of foliar decline symptoms as a function of average soil exchangeable-potassium (K) in the 5 to 25 inch depth in the soil profile. Note that about 70 fields are represented in figure 2, and fields dominated by severe incidence of Verticillium wilt were excluded from this figure. All fields represented in figure 2 had Verticillium incidence (evaluated by foliar and vascular staining symptoms on 30 plants per plot) that was below 25 percent.

Strip applications of soil applied potassium (200 or 400 pounds K_2O per acre) at seven Kern County Pima and Acala fields have been inconsistent (some positive effects, mostly neutral or slight negative effects) in alleviating "late season decline" symptoms. This includes four sites where soil test exchangeable-K levels were not at borderline levels as defined in UC Potassium Guidelines for cotton. Soil test exchangeable-K levels greater than 140 ppm in the upper 2 feet of soil, combined with low plant tissue K, P, and N values 2 to 4 weeks after peak bloom at these sites suggest that the low tissue K levels and to some degree, even the leaf "reddening" or “bronzing" may not be indicative of limiting soil K, but perhaps may indicate a compromised root system not able to fully access soil K or other nutrients.

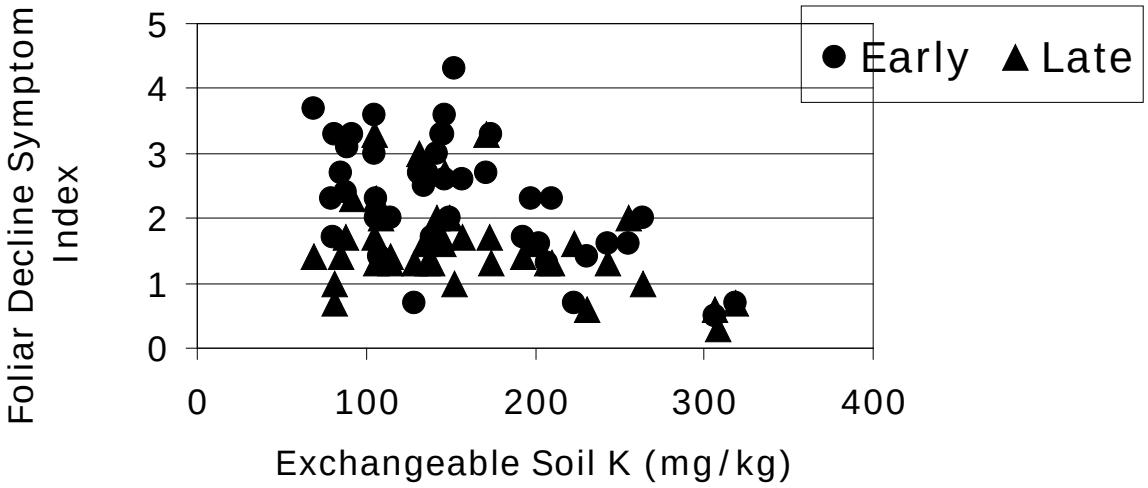

Figure 2. Early decline symptom severity evaluated within 2 to 4 weeks after cutout as affected by exchangeable soil potassium (K) in fields where the symptoms were observed relatively “early” versus relatively “late”. “Early” is defined as symptoms were seen as early as 15 to 17 total plant nodes, while “late” grouping signifies the presence of more than 17 total nodes at the time of first observations of clear symptoms. The foliar decline index will be defined in a paper under development, but higher numbers in severity indicate a greater percentage of total plants affected and more severe foliar injury.

In fields where plants were affected relatively early by this foliar decline, plants generally were low vigor, short-stature plants with a definite slowing of growth and damage to meristems and foliage starting as early as the 15th to 18th main stem node (mid- to late-July in fields). The "leaf decline” or “bronzing” symptoms were not restricted, however, to low vigor fields with irregular growth. At least 7 large and relatively uniform Pima fields in Kern County with previously vigorous, 40+ inch tall plants developed very uniform "bronzing" starting in early- to mid-September. In the late-season, plants typically experience a major drop in leaf and stem potassium levels associated with high K requirements for boll development. At this time of the year, it is not unusual to find near-deficient tissue K levels. Particularly in plants with a compromised root system or general low vigor, boll maturation will take place at the expense of new vegetative growth.

Speculation and field evaluations regarding potential causes of foliar decline problems have considered salinity or sodium toxicity, drainage problems, nutrient deficiencies, rapid boll loading, and Verticillium wilt. Work reported by Richard Percy (USDA-ARS Maricopa, AZ), Hutmacher and Wright (Univ. CA) looked at Pima varietal differences in early decline symptoms and heritability in a two-field study done in California where fields were identified where there was significant history of early decline late-season symptoms. Trials monitored and rated development of early decline symptoms (bronzing, terminal growth cessation), evaluated leaf and petiole nutrient levels, and evaluated tap root samples in select varieties for damage and extent of rooting. Goals were to establish if any relationships existed between symptom development and in particular tissue K levels. Evaluations of germplasm for relative tolerance to early decline showed low heritability and limited tolerance even with severe symptoms early to mid-bloom. Fruit removal studies were also conducted on a limited number of varieties to identify impacts of fruit load on symptom development. A boll removal evaluation was conducted at two sites where most Pima varieties planted developed at least moderate early decline foliar symptoms within the first 1-3 weeks after peak bloom. When either 1/3 or ½ of total plant boll loads were removed manually during the first four weeks of bloom in these plots, the timing of development of early decline symptoms was delayed by at least 2 weeks and the severity of symptoms was significantly reduced (Figure 3). Data from one fruit removal trial in Pima cotton in 2002 where a portion of the young bolls (< 5 days old) were removed manually twice per week are summarized in Figure 3.

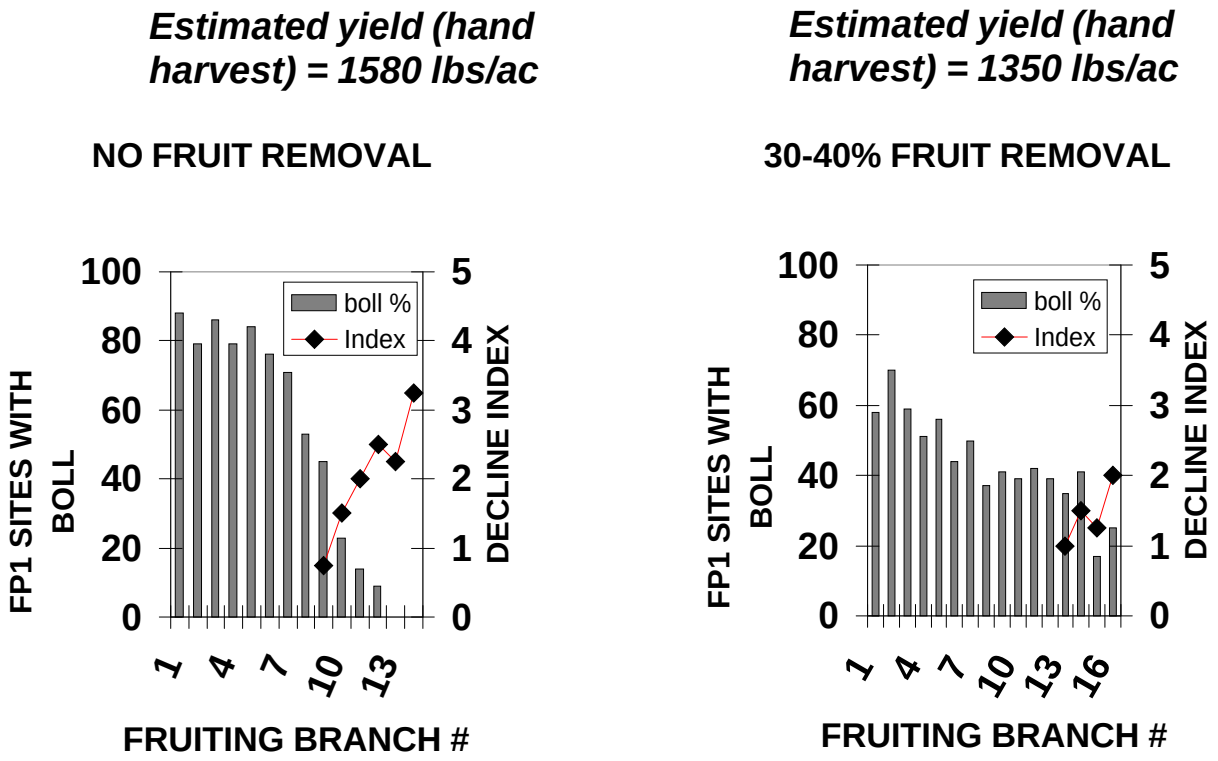

Figure 3. Average retention of first position fruit and timing and severity of development of symptoms of late season foliar decline across three field replications for (left graph) plants with unaltered fruit retention and (right graph) manual removal of 1/3 to ½ of the developing small bolls. Bar graphs show boll retention percent and markers/lines show foliar decline symptom index (as used in other figures). Yield differences between NO FRUIT REMOVAL and 30-40% REMOVAL plots are as shown.

Summary and Future Research Needs

There do not appear to be any specific cures to the problems of "late season decline" based on our field evaluations. Data on fruit load / leaf weight or leaf area ratios suggests that where problems have been seen with early leaf loss

and leaf "bronzing", growers should monitor plant vigor relative to developing boll load. We postulate that plants with a relatively heavy boll load and low vigor as indicated by a measure such as height:node ratios may be at greater risk for early leaf decline. Under such conditions, growth regulator applications not called for according to vigor or fruit retention guidelines, or delayed irrigations or other stresses might be expected to amplify the problems. There are numerous observations that some varieties appear to be much less affected than others in terms of time of development and prevalence of “early decline” symptoms. While cooperators in these field evaluations agree on the existence of varietal differences, some cautions are offered relative to interpretation of the utility of a variety’s ability to remain “green” and avoid “late season decline”. In several variety trials we have observed that some varieties which have shown little evidence of “late season foliar decline” also have been relatively low yielding varieties or varieties with a moderate to low boll load per unit leaf area for that site or year. Some caution is warranted against taking the easy way out and selecting varieties for early decline situations just based on lack of late season decline or leaf symptoms, since low boll loads have consistently been observed to reduce incidence of symptoms. It might further be hypothesized that field conditions producing root damage or limits to root system development could produce earlier and more severe “leaf decline” symptoms. This hypothesis is based on field observations and tap root measurements made in fields in 1997-1999 in Pima and 2002 and 2004 in Acala. Based on the combination of observations reported here, we suggest that the most likely situation for significant problems with early decline and leaf loss occurs when weak root development (limited lateral root formation, limited rooting depth) is combined with relatively low leaf area and moderate to high fruit loads. However, this is certainly not the only situation where “bronzing” or “reddening” symptoms or early leaf loss have been observed. Some of the overall plant "decline" is likely due in part to nutrient deficiencies (K, P, even N) brought on by a weak root system unable to "explore" soil for adequate nutrients and even water. In many of the tested fields described here, "deficiency" symptoms in plants under these conditions have not been associated with levels of soil K, P or N generally described as “deficient” according to University of California guidelines. Rather, "deficiencies" may largely be a function of inadequate root activity and limited root distribution for adequate uptake of nutrients.