The Development and Delivery Of A Crop Monitoring Program For Upland And Pima Cotton in Arizona.

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Abstract

A crop monitoring program has been developed specifically for varieties and environmental conditions unique to Arizona. The monitoring program involves early season development guidelines, growth stage guidelines, and in-season evaluation of crop condition (vegetative/reproductive balance and fruit retention), by use of simple measurements such as height:node ratios (HNR), nodes above the top white bloom (NAWB) counts, and fruit retention estimates from plant mapping. The preliminary work necessary in terms of providing accurate and precise descriptions of the various crop development parameters has been provided through a detailed cotton phenology project conducted over many site-years of experimental work. The resultant baselines describing crop development/monitoring parameters have been scaled as a function heat unit (HU, 86/55^0 F thresholds) accumulations. Application of these baselines have been developed through another facet of the research program to provide a basis for a feedback approach to crop management for inputs such as water, nitrogen (N), plant growth regulators, etc.. The crop monitoring program serves as a fundamental component to an active extension education program being delivered on a statewide basis to all cotton producing areas in Arizona.

Introduction

A cotton (Gossypium spp.) crop, like many other biological entities, goes through a process in growth and development that is fairly predictable. However, as any farmer is well aware, the variations experienced in this "regular" pattern of development can often spell either success or disaster.

Therefore, it is with a great deal of interest that any of us involved in crop production follow these patterns in development, and attempt to use some set of standards to estimate the general conditions of a crop, as well as what might be done to maintain or improve upon this condition.

Quite often, the important stages of cotton crop development are described in terms of calendar dates or as the number of days after planting (DAP). Cotton (and plants in general) respond directly to the temperature and environmental conditions to which they are exposed. As a result, various types of heat unit (HU) systems have been developed to assist in predicting and/or projecting plant development. In Arizona we commonly use HUs with 86 and 55°F thresholds to describe the development of cotton and some insect pests (Brown, 1989). This information is collected routinely at numerous AZMET weather stations located throughout the state and operated through The University of Arizona. So fortunately, we have an easy access to crop/weather related information that can be useful in crop and pest management. We have found that the use of HUs provides a better way of describing cotton development than the conventional calendar and serves to standardize regional (location) or seasonal (year to year) variability (Silvertooth et al., 1991a and Silvertooth et al., 1992a). The purpose in this article is to briefly describe some of the basic plant measurements that can be used to estimate stage of growth and general condition of cotton, and the procedures used to educate/train growers and crop managers to use such measurements in Arizona.

Materials and Methods

Over the past six seasons (1987-1992) a considerable amount of plant measurement data has been collected from many field experiments that have been conducted across the state (48 site-years of data used to date), involving numerous varieties of both Upland (G. hirsutum L.) and Pima (G. barbadense L.) cotton. The intention has been to not only provide a documentation of crop development in each of the experimental cases, but also to develop a collection of data from which general crop development patterns could possibly be described. Data on the number of HUs necessary to achieve points in crop development such as pinhead square, matchhead square, first bloom and cut-out have been collected in all cases. Measurements such as plant height, number of mainstem nodes, flowers per unit area, nodes above the top white bloom (NAWB), and plant mappings have also been routinely made over the growing season. All HU data was obtained from the AZMET system and the weather station closest to the field location under study. Review and analysis of this data has revealed some very consistent patterns in crop development and also a good description of normal variation that one may encounter, as well as what might represent abnormal development or a problem (or potential problem) field. It is our intention to extract from this data a set of guidelines that can be useful in crop management through the use of some simple measurements. The measurements need to be easy to make, and there must be a set of guidelines or standards available for reference.

Results and Discussion

The development of cotton plants in the early stages of the growing season can be predicted rather well by measuring HU accumulations since the date of planting (HUAP). As shown in Figure 1, pinhead square, first square size susceptible to pink bollworm (susceptible square), and first bloom can be expected to occur when approximately 700, 900, and 1200 HU have accumulated since planting, respectively. These HUAP accumulations are not offered as exact or absolute values, and in practice these values should be regarded as general signposts where the occurrence of such events may be expected to occur. For example, the presence of pinhead squares in a field should be expected at about 700 HUAP, but could be noticed as early as 600 HUAP. This 700 HUAP value should, however, be fairly close if plants are initiating first fruiting branches at five to seven nodes above the cotyledonary nodes. If plants are initiating first fruiting branches substantially above node seven, then the occurrence of pinhead squares, and all subsequent events, will also be delayed accordingly. One should also take into account plant to plant variability, and also variability that can occur within a field or among fields in terms of microclimate differences; where warmer spots or areas have a tendency to produce faster developing plants. Most of us recognize that even among several fields within the same farm, each field will be somewhat distinct due to soil types and the general topography, or what is commonly referred to as the "lay of the land". This type of variation can lead to slight differences in crop or pest development, and may be detected if one is closely following a crop in relation to HU accumulations. Variation among varietal types can also be noted, with more indeterminate varieties often requiring more HUs to reach a given physiological event.

Scouting fields for pinhead squares, matchhead squares, and first bloom can help establish criteria for early season management for insects (pinhead square treatments for pink bollworms for example), plant growth regulators (Silvertooth et al., 1989; Silvertooth et al., 1990b; Silvertooth et al., 1991c; and Husman et al., 1992), and nitrogen (N) applications (Silvertooth et al., 1990a; Silvertooth and Doerge, 1990; Silvertooth et al., 1991b; and Silvertooth et al., 1992b). Identification of the occurrence of some of these events are important in that they are some of the first signs that we can use in determining how the young crop is beginning to develop, and how management may need to be adjusted accordingly.

As the cotton crop goes through its pattern of development, we commonly refer to the basic stages associated with the general flower curve shown in Figure 2. To follow a crop's development in relation to a flower curve requires the collection of flower (fresh blooms) counts within a given area on regular intervals. Another measure which has proven to be much easier to make and is still very reliable is the NAWB (number of nodes above the top white bloom). By counting the NAWB, for mainstem blooms within the first two positions on the fruiting branches (not vegetative branches), a good measure of a crop's development over the fruiting cycle can be made. The information shown in Table 1 outlines the NAWB values that relate to specific stages on the fruiting cycle. For example, at early bloom we can commonly expect about 10 NAWB. This value (NAWB) will decrease as the crop approaches cut-out, where it will move to five or less. The rate at which this occurs, or the length of the primary fruiting cycle may vary. The variation can be due in part to variety. Short season varieties will of course be expected to go through a fruiting cycle faster than medium or full season varieties. The general ranges in HUAP for a crop to move toward cut-out are shown in Table 2 for general variety types. These ranges can each be regarded as satisfactory or normal. Pre-mature cut-out could be an indication of crop stresses (i.e. water, salt, pests, etc.) that have occurred. Also delayed cut-out in this sense could be a strong indication of a light boll load (poor fruit retention can be possibly verified by plant mapping) and a good potential of having a late crop. This type of information can serve in assisting a grower in assessing crop condition and developing appropriate steps in management (i.e. water, N, or PGR inputs).

The primary fruiting cycle is critical to the development and realization of good yields. By use of a simple measure such as NAWB, we can follow a crop over the first fruiting cycle and use it as a general signpost for development. This can be of particular value in projecting crop maturity and the occurrence of cut-out in relation to the timing of the final irrigation.

As a crop does progress through the critical stages of the first fruiting cycle, elements of major concern are often associated with the crop's vegetative/reproductive balance. We are working with plant mapping as a means of actually measuring a crop's fruit load and developing guidelines to determine what should be expected or acceptable. The fruit retention baseline for Upland and Pima cotton in Arizona is shown in Figure 3. Another measure that is easy to make and helps in this regard is the height (inches): mainstem node ratio (HNR). This is made by simply counting the number of mainstem nodes (above the cotyledonary nodes) and measuring the plant height in inches. The resultant HNR can be compared to reference guidelines (UA Extension) that serve to describe an acceptable range for proper crop development (Figures 4 and 5). This HNR is useful because we find that the mainstem nodes are developed rather regularly at a rate of about one node/100 HUs under non-stressed conditions (Silvertooth et al., 1991a and Silvertooth et al., 1992a). Therefore, differences that exist between two similar crops, planted at a similar date, in terms of vegetative development can be taken into account by the length of the internodes. We do not have to necessarily focus in on specific internodes, but rather look for the expression of this condition through the overall HNR of the plant. A vegetative plant for example will have a larger HNR than a similar crop which is carrying a better fruit load. One of the interesting features concerning the HNR is that the relationships we have developed from the existing data show an amazing level of similarity among many Upland varieties and even with Pima cotton (Figures 4 and 5). For example, from about 500 - 1500 HUAP, an HNR of 1.5 or greater may be an indication of a crop with a vegetative tendency. On the other hand, over this same period of development a HNR of 0.5 or less may indicate early season plant stresses and insufficient development of a basic plant structure needed to carry a boll load. In either case, the HNR should only indicate the need for further, closer evaluation of the crop. The use of HNR and/or plant mapping (fruit retention) information as a measure of a crop's vegetative reproductive balance serve as the basis for current recommendations concerning the use of some plant growth regulators, such as PIX_{TM} (Silvertooth et al., 1989; Silvertooth et al., 1990b; Silvertooth et al., 1991c; and Husman et al., 1992). Crop vigor and fruit load development are also important factors in making effective use of N fertilizer inputs and provide useful tools in fertility program management (Silvertooth and Doerge, 1990; Silvertooth et al., 1990a; Silvertooth et al., 1991b; and Silvertooth et al., 1992b).

The use and reference of the baselines associated with the basic plant measurements described are being extended to cotton farmers, managers, and consultants across cotton growing areas of Arizona through Extension education programs and meetings, field workshops during the growing season, and written publications. This information is also being incorporated into the University of Arizona Cotton Advisory, which is distributed weekly on a county basis, throughout the growing season (Brown et al., 1992). These advisories provide weekly updates for a given area regarding HU accumulations for various planting dates, insect pest information, and pertinent agronomic information. The advisories make frequent references to the crop monitoring system, particularly during critical stages in the crop's development.

Any of these measurements held alone or by themselves will not serve as sufficient means for making crop management decisions. The intention of these measurements are to serve as tools in assisting a farmer or consultant in the process of making an assessment of a cotton crop's development and condition. Measuring the NAWB, keeping track of HUs, or taking HNRs are not likely to revolutionize the basic way that most farmers grow cotton. But it is true that the health and productivity of the cotton plant is critical to the livelihood of a lot of farmers in Arizona. Accordingly, any improvement or refinement in our understanding of the cotton plant itself could very likely offer benefit to the management and productivity of a crop. Such crop monitoring techniques contribute greatly to any attempts in managing crop inputs based upon actual conditions (feedback approach), versus a less flexible, scheduled basis, of management. The use of simple plant measurements represent just one additional tool that can be used in monitoring cotton growth and development, and could possibly serve to enhance the time honored method of experience and intuition.

Table 1. Relationships between cotton growth stage and the number of nodes above the top white bloom (NAWB).

Growth State	NAWB *
Early Bloom	9 - 11
Peak Bloom	7 - 8
Cut-out	≤5

* NAWB, first or second position fruiting sites on mainstem fruiting branches.

Table 2. General cut-out ranges for cotton variety types commonly grown in Arizona.

Variety Type	HU at Cut-Out*
Short Season	2000 - 2700
Mid Season	2300 - 3000
Full Season	2500 - 3200

* Heat Units (86/55°F) accumulated since planting.

References

1. Brown, P. W. 1989. Heat Units. Bulletin No. 8915, University of Arizona Cooperative Extension, College of Agriculture, Tucson, AZ 85721.

2. Brown, P. W., B. Russell, J. C. Silvertooth, L. Moore, S. Stedman, G. Thacker, L. Hood, S. Husman, D. Howell, and R. Cluff. 1992. The Arizona cotton advisory program. Cotton, A College of Agriculture Report. Series P-91, University of Arizona, Tucson, AZ. p. 233-240.

3. Husman, S. H., J. C. Silvertooth, and C. Ramsey. 1992. The effects of PIX application timing on lint yield and growth and development parameters. Cotton, A College of Agriculture Report. Series P-91, University of Arizona, College of Agriculture, Tucson, AZ. p. 25-32.

4. Silvertooth, J. C., D. R. Howell, C. R. Farr, and J. E. Malcuit. 1989. Evaluations of PIX multiple application treatments on Upland and Pima cotton in Arizona, 1988. Cotton, A College of Agriculture Report. Series P-77, University of Arizona, College of Agriculture, Tucson, AZ. p. 104-109.

5. Silvertooth, J. C., L. J. Clark, E. W. Carpenter, J. E. Malcuit, P. T. Else, and T. A. Doerge. 1990a. Nitrogen management in irrigated cotton. Cotton, A College of Agriculture Report. Series P-81, University of Arizona, College of Agriculture, Tucson, AZ. p. 162-169.

6. Silvertooth, J. C., and T. A. Doerge. 1990. Nitrogen management in Arizona cotton production - Report 9024. The University of Arizona, College of Agriculture. 4pp.

7. Silvertooth, J. C., J. E. Malcuit, D. R. Howell, and C. R. Farr. 1990b. PIX multiple application evaluations in Arizona in Upland and Pima cotton, 1989. Cotton, A College of Agriculture Report. Series P-81, University of Arizona, College of Agriculture, Tucson, AZ. p. 58-66.

8. Silvertooth, J. C., P. W. Brown, and J. E. Malcuit. 1991a. Basic cotton crop development. Cotton, A College of Agriculture Report. Series P-87, University of Arizona, College of Agriculture, Tucson, AZ. p. 43-49.

9. Silvertooth, J. C., L. J. Clark, J. E. Malcuit, E. W. Carpenter, T. A. Doerge, and J. E. Watson. 1991b. Nitrogen management experiments for Upland and Pima cotton, 1990. Cotton, A College of Agriculture Report. Series P-87, University of Arizona, College of Agriculture, Tucson, AZ. p. 209-221.

10. Silvertooth, J. C., J. E. Malcuit, S. H. Husman, S. S. Winans, and L. Hood. 1991c. Cotton response to multiple applications of PIX, 1990. Cotton, A College of Agriculture Report. Series P-87, University of Arizona, College of Agriculture, Tucson, AZ. p. 55-68.

11. Silvertooth, J. C., P. W. Brown, and J. E. Malcuit. 1992a. Cotton crop growth and development patterns. Cotton, A College of Agriculture Report. Series P-91, University of Arizona, Tucson, AZ. p. 9-24.

12. Silvertooth, J. C., L. J. Clark, J. E. Malcuit, E. W. Carpenter, T. A. Doerge, and J. E. Watson. 1992b. Nitrogen management experiments for Upland and Pima cotton. Cotton, A college of Agriculture Report. Series P-91, University of Arizona, Tucson, AZ. p. 183-198.

Planting Date		Pinhead Square	Susceptible Squares		First Bloom	
0	500	700	900	1000	1200	1500
HU (86/55°F)						

Figure 1. Early season cotton plant development as a function of heat units (86/55°F).

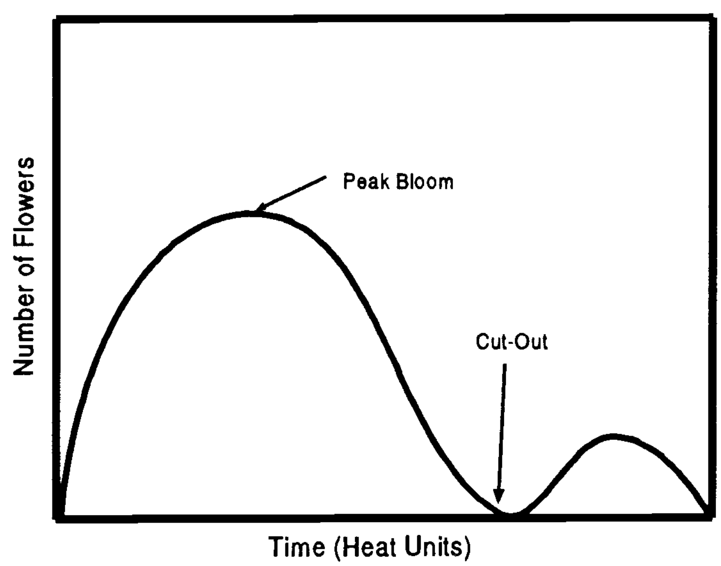

Figure 2. Generalilzed flower curve for Arizona cotton varieties.

A

B

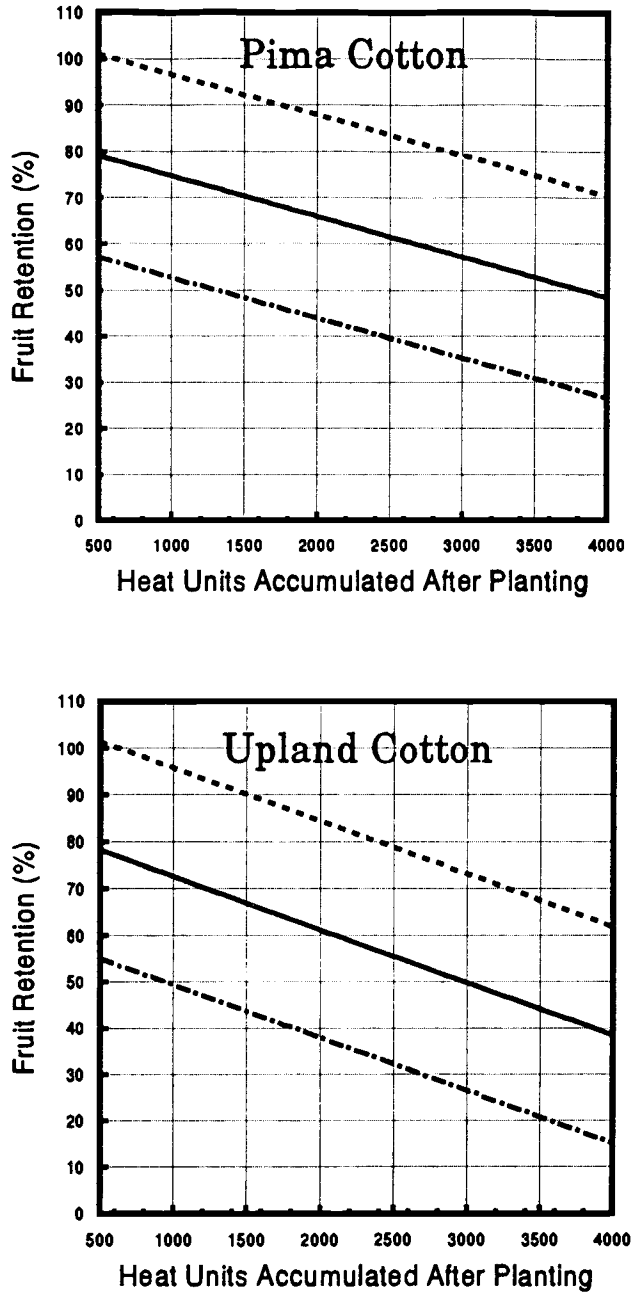

Figure 3. Fruit retention baseline for A) Pima and B) upland cotton in Arizona.

A

B

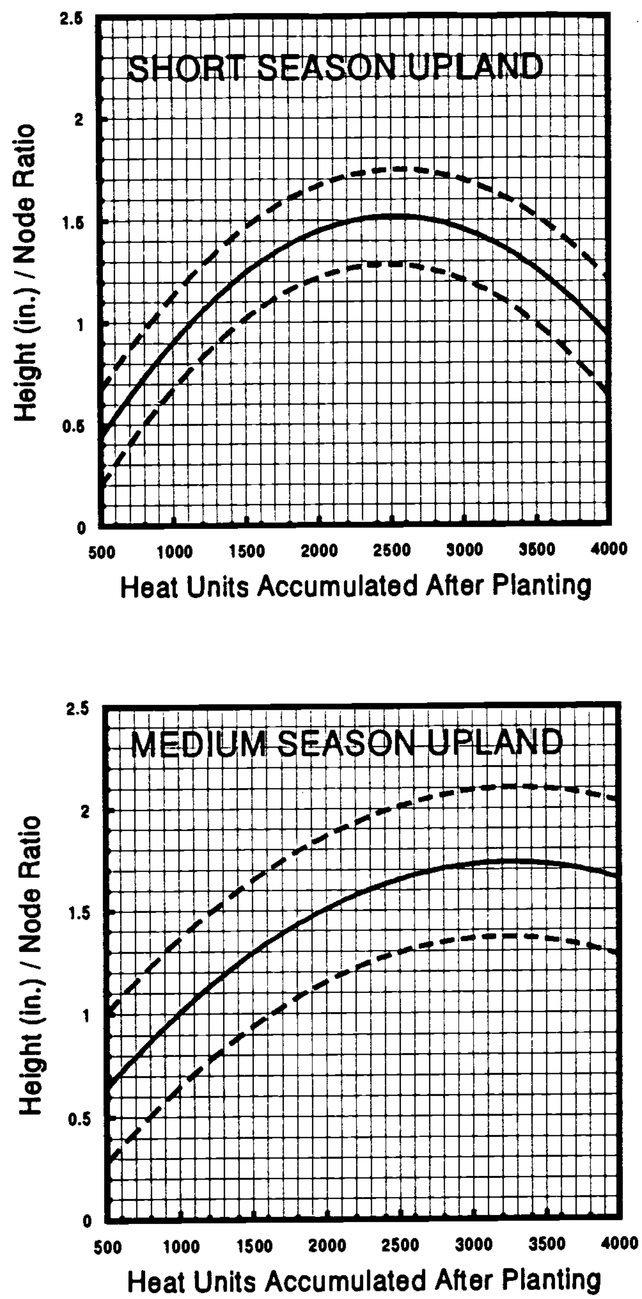

Figure 4. Height (inches):Node ratios for A) short season, and B) medium season upland varieties in Arizona.

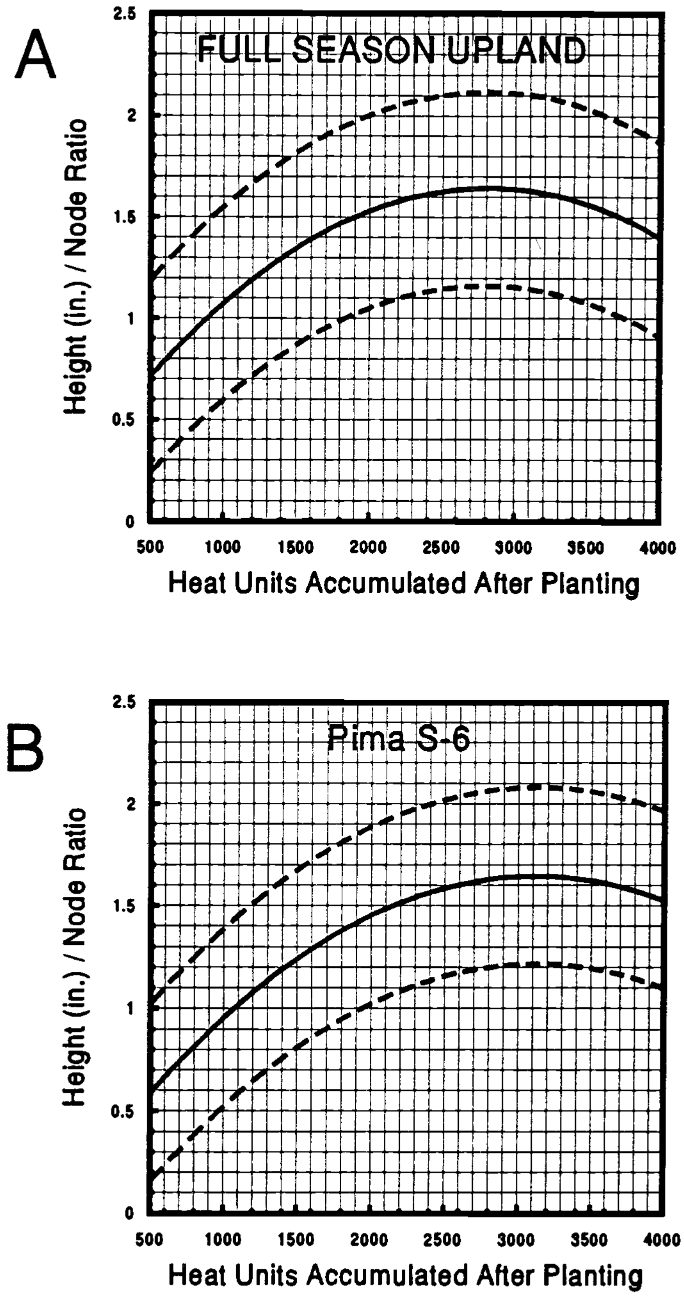

Figure 5. Height (inches):Node ratios for A) long season upland, and B) Pima S-6 cotton varieties in Arizona.