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Managing and Evaluation of Variation

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Cotton is no exception to the general rule that all biological systems exhibit variation. In essence, the causes of cotton variation are many: genetics, weather and management, just to name a few. The results of which cause variation in yield, earliness, fiber quality and the economics of production. The HVI classing system recognizes many classes in fiber, color, trash levels, length, uniformity, strength and micronaire. This is indicative of the complex interactions that these casual factors have on variability. Biological systems that do not successfully adapt to change and variation become extinct. This is true whether you are referring to dinosaurs, passenger pigeons or cotton growers. Therefore, it is imperative that the growers be cognizant of the fact that their survival is dependent upon their knowledge and understanding of source variation. This newsletter focuses on some of the sources of variation and, in particular, source management. Since management is mostly under the control of the grower, it is of critical importance that growers understand and evaluate proposed new management strategies.

A species' ability to adapt, its resiliency, is one measure of evolutionary success. Using resiliency as a yardstick, cotton stands tall. Perhaps the most universally accepted principle of cotton production is that no two fields are exactly alike. In a general sense, there is no such thing as a typical or "normal" cotton crop. Each crop, unique and distinct, reflects the diversity of its biological interaction with the past and present environment.

Upon closer inspection of a cotton field, there can be remarkable variation between individual plants within the field community. Some are short, some are tall, one may be well-fruited while the next is barren, many are healthy and robust, but a few appear sick. This is another manifestation of diversity within a biological system. This variation is not the exception but the rule in cotton production and is partially responsible for the crop's ability to succeed in widely differing habitats from the humid southeast to the arid southwest. In this light, variation can be viewed as a strength.

If variation is a strength, it is also a source of aggravation. Cotton is rightfully viewed as a difficult crop to manage and study. Response to inputs can be obscured by the complex interactions between the plant and its environment. Variation in cotton demands integrated management strategies that consider the impact of inputs on the entire system. In order to develop this strategy, it is worthwhile to consider some of the biological and environmental forces that contribute to the variation of cotton.

Sources of Variation - Biological

It is difficult to imagine or predict that a recently emerged field of cotton can have a bright future. The plant develops from a hesitant seedling in spring into a woody shrub at harvest some 150 to 200 days later. As a woody, indeterminate perennial from the subtropics, cotton is ill-equipped to exploit the early season landscape usually encountered at planting. Instead of developing leaves to capture energy and speed vegetative development, cotton follows its evolutionary road maps by extending its taproot deeper into the soil profile in preparation for a multi-year life span. In its native habitat, cotton contends with the anticipated drought by shedding leaves and young fruiting forms while maturing the older, developed seed. Tissue desiccation or drying is lessened by the presence of a woody stem with a thick bark and a deep, insulated taproot. Upon the return of moisture, vegetative growth can quickly resume as the primary root, and shoot structure is already in place. The indeterminate fruiting habit is well suited to initiating reproduction during favorable environmental windows. Cotton's evolutionary history has programmed the crop to anticipate and prepare for environmental adversity and renewal over an extended period of time.

This successful survival strategy must be accommodated in any attempt to manage cotton as an annual row crop. Transient or localized drought stress in a field tends to increase plant to plant variation within a field. One section may continue flowering and boll loading while another sheds fruit in anticipation of the dry season. This variation is further compounded with the return of adequate moisture. One portion of the field approaches harvestable maturity while the other renews vegetative growth. Different plants with a common genetic background respond uniquely to the same environmental input, moisture in this instance, based on their individual developmental histories. The net result is a variable field with non-uniform crop development, yield and fiber quality.

Environmental

Cotton's subtropical adaptation requires temperatures above approximately 60°F of sufficient duration to allow for vegetative growth, boll development and fiber maturation or at least boll opening. Production areas fulfill

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this requirement in a variety of ways. The accompanying table documents the diverse environments where the crop is commercially successful.

	Northern Coastal Plain	Delta	High Plains	Far West
Season length (days)	150	180	150	>200
Heat Units (DD60s)	2200	3000	2000	3000+
Rainfall	60"	50"	20"	<10"
Soil available Moisture/Foot	1.0"	2.0"	1.5"	2.5"
Rooting Depth	1-2′	2-4′	3-5′	4-6′
Total Available Water	1-2"	4-8"	4.5-7.5"	10-15"

The data demonstrates some of the environmental variability that exists between these production regions. As large as these differences are, they still do not reflect the diversity of environments within each area, particularly as related to soil characteristics.

Each distinct environment dictates the development of a complementing production system. Each region has a set of primary constraints and advantages that must be addressed for profitable production. The Coastal Plains region of the southeast must contend with infertile soils with minimal moisture-holding capacity. On the other hand, frequent summer rains can help compensate for these limitations. The Delta region tends to have deeper, more productive soils but a lower probability of sufficient summer rainfall to produce profitable yields. The High Plains have many productive soils with higher water holding capacity but receive minimal summer rainfall and have a short growing season. The Far West enjoys many desirable environmental features but must contend with permanent drought.

Pest complexes are a significant component contributing to environmental variation. The relative intensity of disease, insect and weed pressures is not uniform across regions of the belt or times of the season. As successful biological competitors, these pests also are adept at developing strategies to resist control practices. With the introduction of each potential competitor, additional complexity is added to the system.

Seasonal

Heat Units Seasonal fluctuations in weather patterns and pest pressures contribute to environmental variation. Heat unit accumulations may vary by over 500 DD60s between seasons with major consequences on crop development. Seasonal variations in total heat unit accumulations are of greatest consequence to the northern margins of the cotton belt where season lengths may limit yield. The relative distribution of heat units also can vary by season with major implications on crop development. Below normal heat unit accumulation delays development in spring and may prevent full maturity in the fall. Conversely, higher than normal heat unit accumulation in mid-summer may adversely impact pollen development and flower fertilization with subsequent delays in boll loading.

Water Availability Similar arguments surround water availability. Periodic drought in rain-fed areas impacts all areas of cotton production from fertilization to pest management to harvest aid selection. Rainfall received from thunderstorms may entail substantial runoff, invalidating uncorrected totals. Seasonal changes in rainfall distribution, particularly in regions with soils that have low water-holding capacity, will introduce additional variation.

Light Intensity Variation in light intensity can have profound consequences on cotton development. Cotton requires high light intensities to produce sufficient photosynthate to support boll loading. Prolonged periods of cloudy or hazy weather reduce boll set and stimulate vegetative growth. This can result in rank growth, delayed maturity and reduced yield and fiber quality. When cloudy weather is accompanied by excessive rainfall, especially during the morning or early afternoon, flowers may not be fertilized as the pollen grains contact water and rupture. Seasonal variation in the interaction of light and water produces a crop that ranges from short, compact and well-fruited to late, rank and barren and everything in between.

Pest population dynamics have a significant seasonal component. Prior population levels and control measures, winter weather patterns and the relative abundance of natural control agents all contribute variation and complexity. Insect pressure must also be considered when assessing the interaction of light, temperature and water. Late developing cotton must contend with higher insect pressure, complicating management and increasing costs.

The significance of seasonal variations in environmental influences can be visualized by imagining that individual cotton production regions behave as floating islands. In selected years, some regions may slide north or south, east or west, depending on local environmental fluctuations. North Carolina cotton may behave like Georgia cotton and High Plains cotton may not behave at all if it slides too far north. This same process may be repeated within seasons as month to month variations are encountered.

Management Interface

The preceding discussion identified independent sources of variation that direct and modulate cotton growth and development in the field. The complex interactions of these forces creates an infinite array of possible field conditions that defies cookbook management strategies that rely on static "universal" cultural practices. Effective management integrates the various inputs into a dynamic system capable of adjustment in response to the fluid landscape. The question is: How is this management systemconstructed?

Progressive cotton management puts a premium on the adoption of technological advances. Research efforts within the public and private sector develop and refine technology that expand the knowledge base reservoirs. A review of field experimentation will shed some light on the relevance of new technology in the development of management strategies.

Research efforts lie along a continuum from basic to applied. While a lively discussion can develop on the location of a specific study, basic cotton research will include investigations of fundamental biochemical or physiological processes that direct plants' metabolic behavior. These studies are routinely conducted in labs using controlled environmental chambers or glasshouses to limit confounding variables. Researchers aware of the impact of variation seek to limit or manage it to isolate the process of interest. Field research, whether basic or applied, is less equipped to isolate variation.

Field researchers must rely on statistical design and analysis to manage and evaluate variation. Without the availability of these mathematically founded procedures, variation can overwhelm observations, obscuring the significance of the results. For example, if two cotton varieties are being compared, is the recorded yield difference due to real enhancement of performance or undefined field variation. In the absence of statistical design and analysis, attempts to distinguish between these two possibilities are futile.

Replication of treatments is central to field experimentation. The procedure consists of initially dividing a test area into smaller subunits, then randomly assigning treatments within these subunits. This design process, varying in complexity depending on the experimental objectives, is performed to isolate, characterize and ultimately manage variation. The reasoning behind this process is that the variation within these subunits should be less than the variation within the entire test area. For instance, one subunit might be a field bottom, while another is a ridge in the same field. It is logical to assume the variation within the bottom (or the ridge) is less than the variation between the bottom and the ridge. By using replications in an experimental design, a researcher can isolate and factor out that portion of the variation in the results that is due to field differences, allowing for more effective evaluation.

Researchers also manage variation by conducting the same experiment at several locations over several years time. This repetition allows the scientist to determine the variation in response due to environmental and/or seasonal interactions with the experimental variables of interest. If the response to the treatments varies by location or season, the researcher can attempt to determine reasons for the differential responses. This ongoing process can spark further experimental inquiries which broaden and refine the knowledge and technological base.

Another aspect of good experimentation is to have appropriate checks to determine if the new management variables — such as varieties, row spacings, fertility treatments, etc. — are truly superior to the current management system. Many errors are made due to the lack of appropriate checks in experiments and grower demonstrations. Appropriate checks are necessary to determine cause and effects; that is, was the favorable or unfavorable observation due to new treatment effects or were they due to being tested in an unusual environment? Due to the many different causes of variation, comparisons of treatments — such as varieties, grown in different fields, planting dates, and years is not valid and very risky. Evaluation statements concerning research results are also often misleading. For example, statements such as "treatment 'A' increased yields up to 30% over the check, fail to mention that treatment 'A' also resulted in yield decreases of 20%, and that the average increase in yield was about 10%. Evaluate all the data, not selected pieces or the extremes. Most researchers report the statistical tests needed to make appropriate treatment comparisons.

These experimental procedures are taken to lessen the probability that detected differences are due to chance (un-managed variation). These same sources of variation are operating in commercial cotton production. However, large scale farming does not lend itself to objective evaluation of new technologies. After repeated small plot experiments detect real potential, and large plot demonstrations illustrate the benefits, commercial adoption of proven technologies can occur.

Local Relevance Careful consideration is warranted when contemplating adoption of unproven technology. Benefits accrued from new technology under one production system may not translate well into another system. Some technologies get very homesick when taken out of their developmental area. Meetings such as the Beltwide Cotton Conferences provide an invaluable forum for workers to share research findings that stimulate discussion, additional studies and technological advances. However, the presentation of promising findings does not constitute proof that they enhance technology on a given farm. Research findings are most relevant to the production system practiced while conducting the trials because attempts have been made to manage the sources of variation encountered within that system. Without that management, the inherent variation of cotton production may dampen or eliminate benefits derived under another system.

Local variations in management philosophy and capability also must be considered. The set of production priorities of novice growers will differ from experienced growers. Weed and insect management are immediate concerns for newcomers. Refinement of fertilization and growth regulation strategies may have to wait if management is already stretched out. Management inputs also will differ in extensive versus intensive systems. One feature common to these differing management systems is that each has a limitation that must be addressed in order to achieve incremental improvements in commercial success. When limitations and opportunities go unrecognized, the adoption of new technology is a shot in the dark.

Progressive management is not conscious of fashions. "New and better" technology deserves scrutiny and skepticism, worthy of consideration if genuine documentation is available. Objective data from other regions support the trial use but not wholesale adoption of technological advances. The variation inherent in cotton requires a cautious approach. The technology may complement one situation and aggravate another.

Finally, it also is useful to approach accepted truths with skepticism. As management systems and expectations evolve, the mix of appropriate practices must be realigned. Unquestioned reliance on dogmatic principles is only slightly less dangerous than feverish embraces of untested technologies. There is a tendency by some growers to incorporate all new proposed management systems. Any new system should be economically superior to the old system. Variation is a cornerstone of biological systems and understanding, and is the ultimate key to better management. Management systems must be flexible in order to make the utmost use of their specific growing conditions and new innovations that are offered.

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