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Physiology of PIX

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Proper use of agricultural chemicals requires a thorough understanding of how a product works. No longer is it enough to know what pests a product controls. We need to understand the ag-chemical's residual effect, resistance status, effect on non-target insects, decomposition routes, etc. Plant Growth Regulators epitomize the need for knowledge about how a product works because optimum rate and timing is dependent on both the plant and the environment. To use a PGR, we need to go beyond the sales hype of "It increases yield!". For example, over the last 10 years researchers, producers and consultants have refined the use of PIX by developing a "feel" for how PIX works and taking into account the plant's growth rate, fruit retention and stresses which may impact the crop. This newsletter is designed to expand this knowledge base.

Plant Hormones

Plants and animals have obvious differences when viewed from the naked eye, but as higher and higher levels of magnification are used to compare them, the differences become fewer. For example, many of the same cell components are used by plants and animals; and upon even closer inspection, the chemical reactions employed to power the cells are virtually identical.

The role of hormones in plant growth has been confused by attempts to translate what we know about animal hormones over to plants. Animal hormones act very differently from plant hormones. Animal hormones are clearly produced in one site, such as a gland, and then transported via the circulatory system to another site, such as the ovary, where the hormone's concentration regulates the effect.

Plant hormones on the other hand are produced throughout the plant and have both local and distant effects on a multitude of plant functions. Unlike animals, no specific plant growth or sex hormone has been found despite intense scrutiny. The closer one looks at plant hormones the more diverse is their effect, and the more likely that additional classes of chemicals also will qualify as "hormones".

Gibberellin

PIX reduces the synthesis of Gibberellic Acid (GA), one of the recognized classes of plant hormones. This hormone was discovered accidentally during research into a disease that causes spectacular growth and subsequent lodging of rice. Japanese researchers discovered that a fungus Gibberella fujikuroi produces a large amount of GA_3, GA_4 and GA_7, several of the many GA's that have been identified. GA's promote cell expansion, in addition to a multitude of other effects. Cells — whether lint fibers or leaf cells — expand when both (1) new cell wall is produced and (2) the internal pressure within stretches the cell wall. If cell wall synthesis or internal pressure is reduced, then growth slows or even stops. This is the reason that cold temperature slows expansive growth; cell wall and internal components are not produced as fast. Likewise, water stress decreases the pressure inside cells and slows elongation. GA is thought to promote elongation by loosening the cell wall either directly by altering wall pH or indirectly by turning on enzymes. It is known that GA stimulates fiber elongation in the very early stages that occur immediately after bloom.

PIX Reduces GA Biosynthesis

PIX partially inhibits one of the enzymes that is involved in GA biosynthesis. Since GA has many effects and obviously some cell elongation is necessary, complete inhibition of GA synthesis is undesirable. This is the reason that the rate of PIX is critical to final plant size and yield. Either too high or too low a PIX concentration in the plant results in either too much or too little growth control. The concentration of PIX in the plant is dependent on the rate applied and plant size. Applying 1/2 pt (.022 lbs a.i. per acre) at early bloom has a similar effect on growth control as 1 pt, 10 days later when the plant has grown significantly larger. After PIX is applied, the concentration decreases as the molecule is diluted by plant growth.

History

PIX (N,N-dimethylpiperidinium chloride) was discovered by scrutinizing the various molecules that restrict growth — other anti-gibberellins — and then designing a new molecule that would work much the same way. This method of discovery has worked well for other classes of ag-chemicals such as insecticides and herbicides, where families of products (for example, pyrethroids and triazines) have provided numerous products to control pests. In the family of anti-gibberellins, other molecules have been successfully developed for ornamentals, tree crops and small grains.

PIX Effects on Leaves and Stems

Most of the effects that PIX has on cotton appear to result from the suppression of cell enlargement. The smaller cells in PIX-treated cotton result in a 5 to 10% reduction in Leaf Area Index (LAI). Although PIX treated leaves are smaller, they are also thicker, due to an increased layer of cells that develops. The thicker leaves and smaller cells give the PIX treated cotton a more concentrated dark-green color. Branches are shortened and stem dry weight is reduced by approximately 20%. PIX will not shrink, already expanded leaves and stems, only limit further expansion. In general, PIX-treated cotton puts less energy and growth into leaves and stems and more into fruit retention and boll development.

Movement in the Plant

Uptake of PIX is rapid. Within 8 hours 70-90% has moved into the plant. The addition of an EPA-exempt surfactant can shorten the rain safe period to 4 hours. PIX is somewhat mobile within the plant, moving both up, in the transpirational stream (xylem) from roots to leaves and down, in the sap (phloem) from leaves to sinks. Thus application to the top of the plant results in some redistribution throughout the plant — with the highest concentration going to where it is needed, the young still expanding leaves, branches and internodes.

PIX Effects on the Whole Plant

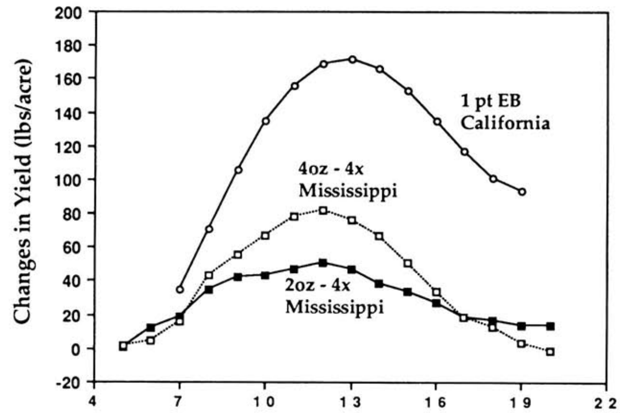
Plant Shape

One of the earliest PIX observations was that cotton tended to be shorter, narrower and have smaller leaves. This has been the most consistent effect of PIX. When applied at the rate of 1/2 pt at early bloom, PIX decreases final plant height by 8-15%. The height control from PIX is directly proportional to the rate (within the label range). Thus, cotton treated with 1 pt of PIX will be approximately 20% shorter than if untreated. If the untreated cotton reaches a final plant height of 50 inches, then PIX treated cotton would be 45 or 40 inches tall at the 1/2 or 1 pt rate. PIX will not restrict plant height to this degree, when stress also shortens the plant. Fields treated with PIX, especially the Low Rate Multiples, often appear to be highly uniform in size and shape, partially due to the higher dose of PIX contacting the taller plants.

Boll Retention

PIX has been shown to have both a positive and negative effect on boll retention, depending on the location of the fruit up the mainstem. The results of 11 replicated experiments in the San Joaquin Valley, where 1 pint of PIX was applied at early bloom, showed that boll retention was increased at the lower nodes. In the middle crop, retention was the same as in the untreated but decreased in the top crop (Kerby, Hake and Keeley 1986). The zone of maximum PIX advantage, occurred through node 12. In this zone (nodes 6 through 12) PIX increased boll retention by 15%. Above this point (node 13 and up) boll retention in the PIX treated plots was decreased by 18%. Thus the maximum boll retention benefit is obtained with short season cotton. Recent work by Russell Hayes and Johnie Jenkins in Mississippi has shown a similar boll retention response with the Low Rate Multiple applications of PIX (2 or 4 oz, 4 times). Their data with DES 119 and DPL 50 shows a maximum boll retention advantage occurring also at node 12. When the crop is extended late into the year, this advantage is negated by reduced retention in the top of the plant. The following figure shows the averages for each of these series of experiments. The yield advantage of PIX is graphed starting at the bottom of the plant, with the yield advantage from each subsequent node added to the previous cumulative total. Thus by node 12 to 13, no further improvement in retention occurred. In fact, above node 13 the PIX advantage lessens and by node 20, in the Mississippi trials, the yield of the PIX plots equalled that of the control. The 4oz LRM, compared to the 2oz rate, generated more bolls in the bottom of the plant but fewer in the top of the plant.

Cumulative, PIX Treated Minus The Control



(Kerby, Hake and Keeley 1986. Russell Hayes 1991)

What Causes This PIX Effect on Retention?

Several hypotheses have been advanced regarding the PIX enhancement of boll retention in the bottom of the plant. One possibility is improved light penetration into the lower canopy due to smaller leaves resulting in a more favorable light environment for the subtending leaf. When 1 pint of PIX was applied at early bloom to a full-season variety (Stoneville 213), light penetration into the lower half of the canopy was increased 20% the 2nd and 3rd week following application, along with a yield increase of 13%. However, the same high rate of PIX, when applied to a compact, short-season variety (TAMCOT CAMD-E) limited plant expansion excessively thereby reducing light penetration into the lower canopy and yield (Niles and Bader 1986).

A second possible explanation for improved boll retention is an enhanced supply of carbohydrates for bolls when PIX limits the growth of leaves and stems. PIX limits vegetation but expands the size of bolls. Lint weight per seed is increased by 3% and seed size by 6% (Bader and Niles 1986). Additionally, the shift of bolls from the top half of the plant to the lower half should increase the average boll size because early set bolls are larger than late set bolls (Jenkins 1990).

The reduced retention in the top of the plant observed with PIX is due to early cutout. The early boll load is increased by PIX, at the same time the early leaf area is restricted. Cotton's ability to sustain boll retention and new node production depends on the balance between the boll load (developing bolls) and carrying capacity (leaf area of young healthy leaves). PIX treated cotton not only has fewer bolls in the top of the plant but also approximately 1 node less. One measurement of the plant's ability to sustain boll retention is

"Nodes Above the White Bloom". This plant mapping technique, explained in the Video and Handbook discussed on page 4, provides a measure of the plant's remaining carrying capacity.

Maturity

One of the benefits from enhanced early season boll retention with PIX is earlier crop maturity, which contributes to short season production. Not only is earliness gained from the shifting of bolls set late in the bloom period to early in the bloom period, but also from earlier cutout. Extension Specialists report an average earlier harvest of 5 to 7 days with PIX. A crop that is set over a shorter time period, opens rapidly, allowing more of the crop to be harvested in the first pick.

Lint and Seed Quality

Other than the effects associated with early crop maturation, PIX produces no measurable effect on lint quality. Early maturing cotton can have increased or decreased quality depending on whether the lint is harvested promptly upon opening or left to weather in the field.

UTILIZATION

Late Planted Cotton

From the previous discussion on boll retention, it should be apparent that a yield response to PIX is anticipated on late planted cotton. Late planted cotton develops its vegetative framework under warm days with maximum day length. As a result, late planted cotton is highly vigorous and growthy. In addition, the early cutout of PIX treated cotton is a positive factor in late planted cotton due to the short growing season. In San Joaquin Valley Research, as planting was delayed from April 2 to May 30, yield dropped from 1122 to 483 without PIX but only from 1121 to 615 with PIX at 1 pt per acre (Kerby 1985). The maximum PIX advantage (approximately 130 lbs of lint) was achieved with all May planting dates. Five years of research in Mississippi also showed an increased response to 1 pt of PIX as planting is delayed. No difference in PIX response was observed regardless of variety, whether early, intermediate or full season maturity.

Planting Date and PIX (Mississippi)

	Planting Date					
	Mid April		Early May		Late May	
	PIX	Control	PIX	Control	PIX	Control
Plant Height	46.4	50.8	46.9	56.7	48.1	60.6
Lint Yield	1301	1363	1457	1382	1195	1060
% 1st Pick	60.2	59.2	64.5	62.1	63.7	60.2

(Cathey and Meredith 1988)

Excess Vegetation

The height control from PIX can be both beneficial and detrimental to yield, depending on the rate and tendency of the field to grow rank. In research trials, PIX response can be partially explained from the end of season plant height of the untreated control. Cotton growers have learned that those fields producing tall cotton due to soil type or water and nutrient availability, respond well to PIX. As expected these relationships are specific for the growing area and variety. Charles Stichler in Texas reports a PIX yield response in stripper varieties when the untreated control is over 24 inches tall, while Tom Kerby in California predicts the greatest yield response in full season cotton that is over 43 inches tall. These two extremes emphasize that short cotton resulting from stress is more likely to respond adversely to PIX than is short cotton resulting from a heavy boll load or varietal characteristic. In the humid Mid-South, full canopy cotton is prone to boll rot. Under these conditions, Al Chambers in Tennessee has shown a strong benefit from PIX in limiting boll rot damage.

Narrow Row Cotton

The effect of PIX on reducing leaf area, plant height and width, has been shown to be highly beneficial when cotton is planted in 30 inch rows. Narrow row cotton can fully intercept the sunlight with plants that are 10 inches narrower than plants in conventional spaced rows. This allows the use of more efficient plant types, plants with less dry weight in leaf and stem. Until varieties are specifically developed for narrow row, the conversion of wide row varieties into narrow row types can be partially accomplished with PIX.

PIX in Full Season Cotton

Whether to apply PIX is an easier decision in narrow row cotton or short season production or where soil and environmental conditions lead to excess vegetation. However, in other fields the decision is less clear. One of the early research concepts was that PIX, when applied to full season cotton, could eliminate the need for plant stress to control growth and instead producers could "push" the crop with more water and nitrogen. This has not been shown to be true. The optimum N and irrigation rate appears to be the same regardless of whether PIX is applied. Stress that prematurely ages leaves or reduces fruit retention is detrimental regardless of whether PIX is applied or not. The need for PIX in full season cotton depends on the need for height control, leaf size control and the need to shift boll retention from late to early in the season. Enhanced early season boll retention provides several indirect benefits such as: improved quality from early bolls, easier management of irrigation and fertilization and reduced vulnerability to late season insects.

PIX and Stressed Cotton

Because PIX acts to decrease the expansion rate of leaves, stems and branches, PIX can compound problems if stress has already restricted expansion. Both cool weather and water stress restrict expansion and plant size. When cotton is experiencing such an expansion limiting stress, PIX should not be applied. The Low Rate Multiple method of PIX applications allows the use of small doses of PIX during periods of non-stress growing conditions and withholding applications during stress. Use of PIX in this manner will avoid expense and yield depression from PIX if applications had been continued during stress.

Confusion has existed in the past as to the appropriateness of PIX when cotton is under stress resulting from insect pressure. Use of the carrying capacity and boll load concept can guide usage under these conditions. Insect feeding on leaves would reduce leaf area or carrying capacity, suggesting that PIX would not be appropriate. On the other hand, where insects injure early season squares, the boll load will be delayed and carbohydrates will be used for explosive vegetative growth during the early bloom period. Under these conditions, a strong response to PIX would be anticipated if square damage is curtailed.

Plant Mapping and PIX

Plant mapping provides an easy method to look at plants and determine if PIX should be applied. Besides row width and planting date, some of the plant factors that influence that decision include: early square retention, plant vigor, node of the 1st fruiting branch and nodes above the white bloom. These various plant mapping techniques are discussed in the Applied Plant Mapping Handbooks available from the National Cotton Council and discussed in the following article. The increased scrutiny from plant mapping or even casual field monitoring allows confidence that PIX is used only where needed. This confidence in the optimum rate and timing of PIX has come from intense research conducted over the last 10 years. Even now, the knowledge base about PIX is still expanding as new questions are asked and answers to older questions refined.

About the Authors

This issue of Cotton Physiology Today was co-authored by the Cotton Specialists Will McCarty (Mississippi), Tom Kerby (California) and James Supak (Texas High Plains) with input from Denny O'Neal (Plant Physiologist for BASF).

"Applied Plant Mapping"

A new series of Applied Plant Mapping Handbooks has recently been developed by the Cotton Physiology Education Program. These guides provide producers and consultants the maximum amount of useful information about their crop with the least amount of time

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