Chapter 6:

SQUAREMAN Decision Aids

James F. Leser, Diana M. Danforth, and Fred M. Bourland

SQUAREMAN decision aids use number of squaring nodes, square retention, and *height-to-node ratios* (HNR) to assist growers with decisions involving irrigation initiation, early-season insect control, in-season fertility, and plant growth regulation. The aids apply to the plant growth and development period prior to the appearance of the first flower. They are diagnostic in nature and designed to identify when fields are under stress or otherwise deviating from optimal growth and development. Suggestions for the course of action growers should follow to remedy potential problems detected through SQUAREMAN are listed where appropriate. Follow-up field verification of a potential problem detected through SQUAREMAN is always recommended. The purpose of this chapter is to enumerate these aids and summarize the triggers associated with them.

Basis for Triggering Decision Aids

SQUAREMAN utilizes SquareMap data to primarily address two crop management questions: 1) Is plant development progressing at the acceptable pace? and 2) Is square retention acceptable?

To address these questions, 45 decision aids (listed under Application of Decision Aids section) have been incorporated into SQUAREMAN, and each is triggered by different combinations of crop development measurements (initiation of node development, rate of node development, plant vigor) and square shed levels (Bourland et al., 1998).

The pace of crop development is determined by sequential measurements of first-position *squaring nodes*. Prior to flowering, the number of squaring nodes corresponds to the number of sympodia (fruiting branches) that develop from the main stem. In SQUAREMAN, first-position squaring nodes are plotted against days from planting and compared to the shape and ascent of the *Target Development Curve* (TDC) to the apogee (*See* Chapter 3).

There are three decision aid bases. *Base I Decision Aids* are triggered by *position* and *slope* of the actual growth curve relative to TDC.

Base II Decision Aids contain decision aids that address changes in square shed rates. In addition to the position and slope of the curve, a third factor used to trigger the decision aids is square retention. SQUAREMAN expresses square retention as the percentage of first-position squares that are shed. The decision aids are then triggered by either a high (>15%) or low (<15%) level of square shed, which is especially useful in anticipating approaching square-retention management decisions and evaluation of any remedial action taken to correct earlier square-retention problems.

Base III Decision Aids use changes in HNR for evaluating *plant vigor* (*See* Chapter 3 for other vigor indices).

Plant Compensation and Square Shed Limits

The cotton plant has the potential for tolerance and/or compensation for early fruit loss (producing many more squares than it can possibly mature into harvestable bolls), depending upon the subsequent management and environmental growing conditions. Previous studies have shown that some levels of early-season square loss under certain conditions rarely affected yields (Kletter and Wallach, 1982; Terry, 1992; Montez and Goodell, 1994; Holman, 1996) and sometimes increased yields (Pedigo et al., 1986; Sadras, 1995; Doederlein et al., 2002) because of the plant's compensation ability. However, early square loss can cause maturity delays even if yield is unaffected (Leser et al., 2004). For every 1% increase in square loss, the crop is delayed by 0.1818 days. These delays can expose growers to a higher risk of adverse weather during harvest and require a higher level of and cost for managing late-season insect infestations (Eaton, 1931; Munro, 1971; Bagwell and Tugwell, 1992; Cochran et al., 1994; Sadras, 1995).

The ability of a crop to compensate for early-season square loss can be affected by several factors including cultivar, planting date, plant density, fertility inputs, yield potential, available heat units, insect infestations, disease, and water stress. Leser et al. (2004) found that where water and heat units were not limiting factors, plants could compensate for most if not all pre-flower square loss (even from second-position fruiting sites). There is a 0.97% yield loss for every 1% square shed rate increase above the compensation capacity of the crop. As yet, research has not been able to provide the information needed to define an individual field's compensation capacity. In irrigated systems, water stress is probably the most relevant factor influencing compensation capacity that is under the control of the grower. Teague et al. (2005) found that delaying irrigation can lead to pre-flower water deficits and a subsequent decrease in the crop's compensation capacity for injury from early-season insect pests.

Since SQUAREMAN monitors only first-position fruit, the ability to monitor the recovery from early-season square loss may be compromised because most compensation takes place in second and third sympodial branch positions rather than by adding nodes through increases in plant height (Leser et al., 2004). By producing more squares than can be matured as harvestable bolls, most fruit-load adjustments in the cotton plant take place through small-boll shed late in the season. Much of the compensation for early-season square loss is through an increase in boll retention rather than an increase in later square retention.

Square loss levels used for early-season insect control decisions vary considerably between states in the Cotton Belt. Texas uses a range of 10 to 25% depending upon location in the state and week of squaring during the pre-flower period (Baugh et al., 2005) while much of the Mid-South has long used 20 to 25% (Johnson and Jones, 1996; Turnipseed et al., 1995). Holman (1996) estimated that square loss lower than 19% at first flower did not affect yields while Johnson and Jones (1996) used 25%, Gutierrez et al. (1981) used 30%, and Leser et al. (2004) used 40% as compensation limits. The 15% square shed limit is the default value used by SQUAREMAN. There is currently no option available to the user to enter a different square shed limit value.

Generalized Interpretations of Base I Decision Aid Trigger Options

Position relative to target (3 options) (*See* Chapter 9 for graphic examples)

Left of target: Early plant development, such as associated with fast emergence and/or rapid development of plant structure, often accompanied by a low first-fruiting node.

Near target: Development at a pace for optimal combination of earliness and yield.

Right of target: Delayed plant development such as associated with high plant density or cool temperatures accompanied with a high first-fruiting node, *or* slow development of plant structure such as associated with low seedling vigor.

Slopes of growth curve prior to apogee (4 options) (*See* Chapter 9 for graphic examples)

Slope flatter than target: Stressed plant growth where intensity of stress is indicated by flatness of curve and fewer number of squaring nodes. Stress related to flattening of the slope between sampling dates after following the TDC slope is often associated with lack of needed moisture to continue optimal growth pace. Late initiation of irrigation is often the cause.

Slope similar to target: Development at optimal pace.

Slope steeper than target: Plant development progressing at a rapid pace, likely evidenced by excess vegetative growth (often associated with fruit shed). When the slope steepens between two sampling dates after being flatter than the TDC, plant stress is most likely relieved, e.g., rain/irrigation if water had been deficient.

Slope not determined: The situation when only one sample date is available.

Square shed (2 options)

High: User should determine the cause of square shed and be aware that significant loss of squares may stimulate excessive vegetative growth. Square shed can be either physiological or insect induced (e.g., thrips, cotton fleahoppers, plant bugs).

Low: User should be prepared to meet high demands for water and nutrients by the developing fruit load.

Application of SQUAREMAN Base I-III Decision Aids

Base I Decision Aid set. The first check is to see if the field is already flowering. If so, then the user should switch from SQUAREMAN to BOLLMAN. If no flowers are present, then there are 24 aids covering combinations of thee observed growth curve positions by four slopes (relative to the TDC prior to the apogee) by two square shed options. Table 1 provides a summary of these Base 1 Decision Aids.

The *Base II Decision Aid* set contains ten more decision aids (*See* Table 2). If the field is already flowering, the user should switch to BOLLMAN. If the field has only one data point, the user must wait until a second sample is taken before square shed rate change can be evaluated.

The *Base III Decision Aid* set contains three decision aids pertaining to evaluating changes to the height-to-node ratio (*See* Table 3). Again, if the field is already flowering, the user should switch to BOLLMAN. At least two sample dates are required for the program to calculate height-to-node ratio change.

Summary

SQUAREMAN decision aids provide a means to evaluate crop development and can often signal potential problems. Users should also consider other information in making management decisions during the pre-flower period (e.g., weather, cultivars, insect infestations, soil factors, moisture situation, field experiences) as well as other SQUAREMAN outputs (e.g., measures of first-fruiting node, estimates of plants per acre, first-position fruit per acre, square shed by position). Integration of this information should help the user to determine the appropriate action to take to maintain optimal pace of crop development and fruit retention.

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Table 1. Base I Decision Aids: Evaluating most recent growth curve and square shed.

Nodal development relative to TDC[z]	Slope relative to TDC (nodal) development pace)[y]	First position square shed rate (High, ≥15%; Low, <15%)	Considerations
Above	Steep	High	Square shed has exceeded 15% and nodal development is faster than normal. Determine the cause of square shed. Monitor plant growth. Excessive vegetative growth has occurred, or is likely.
Above	Steep	Low	Although fruit retention is good, nodal development is faster than normal. This is an unusual (often transient) condition. Continue to monitor plant growth for signs of excessive vegetative growth.
Above	Flat	High	Nodal development is slower than normal which indicates possible plant stress from increased fruit load or certain pest, cultural, or environmental conditions. Square shed has exceeded 15%; determine the cause of square shed.
Above	Flat	Low	Nodal development is slower than normal which indicates possible plant stress from increased fruit load or certain pest, cultural, or environmental conditions. Check for water stress and monitor crop fertility needs. Early infestations, thrips, nematodes, or sublethal seedling disease may be involved. Deficient or excessive water, cool temperatures, cloudy conditions, or herbicide injury may be causes.
Above	Target	High	Square shed has exceeded 15%; determine the cause of square shed. Monitor plant growth; conditions for possible excessive vegetative growth exists.
Above	Target	Low	Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.
Above	1-Sample	High	Field started squaring earlier than normal. Early squaring may be due to fast emergence or develoment of first squares at a relatively low (e.g., <6) main-stem node. Square shed has exceeded 15%; determine cause of shed. Monitor plant growth; conditions for possible excessive vegetative growth exist.
Above	1-Sample	Low	Field started squaring earlier than normal. Early squaring may be due to fast emergence or development of first squares at a relatively low (e.g. <6) main-stem node. Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.
Below	Steep	High	Square shed has exceeded 15% and nodal development is faster than normal. Determine the cause of square shed. Monitor plant growth; excessive vegetative growth has occurred or is likely.
Below	Steep	Low	Although fruit retention is good, nodal development is faster than normal. This is an unusual (often transient) condition.
Below	Flat	High	Nodal development is slower than normal which indicates possible plant stress from increased fruit load or certain pest, cultural, or environmental conditions.
Below	Flat	Low	Nodal development is slower than normal which indicates possible plant stress from increased fruit load or certain pest, cultural, or environmental conditions.
Below	Target	High	Square shed has exceeded 15% -- determine the cause of square shed. Monitor plant growth; conditions for possible excessive vegetative growth exist.
Below	Target	Low	Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.
Below	1-Sample	High	Square shed has exceeded 15%; determine the cause of square shed. Monitor plant growth; conditions for possible excessive vegetative growth exist.

continued

Table 1. Continued.

Nodal development relative to TDC[z]	Slope relative to TDC (nodal) development pace)[y]	1st Position square shed rate (High, ≥15%; Low, <15%)	Considerations
Below	1-Sample	Low	Field started squaring later than normal. Late squaring may be due to slow emergence or development of first squares at a high (e.g. > 7) main-stem node. Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.
Target	Steep	High	Square shed has exceeded 15% and nodal development is faster than normal. Determine the cause of square shed. Monitor plant growth; excessive vegetative growth has occurred or is likely.
Target	Steep	Low	Although fruit retention is good, nodal development is faster than normal. This is an unusual (often transient) condition.
Target load	Flat	High	Nodal development is slower than normal, which indicates possible plant stress from increased fruit or certain pest, cultural, or environmental conditions. Square shed has exceeded 15%; determine the cause of square shed.
Target	Flat	Low	Nodal development is slower than normal which indicates possible plant stress from increased fruit load or certain pest, cultural, or environmental conditions.
Target	Target	High	Square shed has exceeded 15%; determine the cause of square shed. Monitor plant growth; conditions for possible excessive vegetative growth exist.
Target	Target	Low	Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.
Target	1-Sample	High	Square shed has exceeded 15%; determine the cause of square shed. Monitor plant growth; conditions for possible excessive vegetative growth exists.
Target	1-Sample	Low	Fruit retention and nodal development are good. Fruit load may cause increased demands for water and nutrients.

[z] Nodal development relative to TDC is evaluated by comparing observed number of nodes to target number of nodes at days after planting (DAP) for the latest SquareMap sampling date in a field.
To calculate *Target nodes above first square* (NAFS) for the date, start at 0 on 35 DAP and add 0.37 per day.
To calculate *Actual* NAFS for the date, subtract 1 from the # sympodial branches.
Calculate *Ratio* = *Target/Actual*.
If sampling date ≤35 then Development = “Above.”
Otherwise: If *Ratio* ≥ 1.15 then Development = “Above.”
If *Ratio* < 1.15 and *Ratio* >0.86 then Development = “Target.”
If *Ratio* ≤ 0.86 then Development = “Below.”

[y] Slope relative to TDC slope (Pace of nodal development) is evaluated by computing the daily change in nodes between the latest two SquareMap sampling dates and comparing to the daily change expected from the TDC, which is 0.37 nodes/day.
Actual *Rate* of change/day = $(Nodes_t - Nodes_{t-1})/(DAP_t - DAP_{t-1})$
If only one SquareMap sampling date then Pace = “1-Sample.”
Otherwise: If *Rate* ≥ 0.49 then Pace = “Steep.”
If *Rate* < 0.49 and Pace > 0.25 then Pace = “Target.”
If *Rate* ≤ 0.25 then Pace = “Flat.”

Table 2. Base II Decision Aids: Evaluating square shed rate change between consecutive sampling dates

Shed rate change	Current shed rate	Previous shed rate	Considerations
No change			The square shed rate has not significantly changed since the previous data collection date.
	< 15%	< 15%	The shed rate has remained below 15% on both sampling dates.
	< 15%	≥ 15%	The shed rate was at or above 15% on the previous sampling date and is now below 15%.
	≥ 15%	< 15%	The shed rate was below 15% on the previous sampling date and is now at or above 15%.
	≥ 15%	≥ 15%	The shed rate has remained above 15% on the latest two sampling dates. Determine whether square shed is insect or physiologically induced.
Significant decrease			The square shed rate has significantly decreased since the previous data collection date. This may indicate recovery from a previous problem.
	< 15%	< 15%	The shed rate remained below 15% on both sampling dates.
	< 15%	≥ 15%	The shed rate was at or above 15% and is now below 15%.
	≥ 15%	≥ 15%	The shed rate has remained at or above 15% on both sampling dates. Determine whether square shed is insect or physiologically induced.
Significant increase			The square shed rate has significantly increased since the previous data collection date. This may or may not indicate a problem.
	< 15%	< 15%	The shed rate has remained below 15% on both sampling dates.
	≥ 15%	< 15%	The shed rate was below 15% and is now at or above 15%. Determine whether square shed is insect or physiologically induced.
	≥ 15%	≥ 15%	The shed rate was above 15% and has further increased. Determine why square shed continues to increase. Determine whether square shed is insect or physiologically induced.

Table 3. Base III Decision Aids: Evaluating height-to-node ratio (HNR) change between consecutive sampling dates.

Change in HNR	Considerations
No change	No significant change in HNR has occurred since the previous data collection date.
Significant decrease	The HNR has significantly decreased since the previous data collection date. Plant stress is indicated. Check for aphid infestations, water stress or other factors that may inhibit plant development.
Significant increase	The HNR has significantly increased since the previous data collection date. Excessive growth is indicated. Check square retention and plant vigor and determine whether vegetative growth should be controlled.