Interpretation of Crop Growth Patterns Generated by COTMAN

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INTRODUCTION

The COTMAN plant growth monitoring program consists of two expert systems: SQUAREMAN, which uses SquareMap data, and BOLLMAN, which uses nodes-above-white-flower (NAWF) data (Oosterhuis et al., 1996). Both expert systems primarily utilize one common plant measurement, the number of *squaring nodes*. *Squaring nodes* is defined as the number of fruiting branches (sympodia) that have a square, or a shed square, in the first position from the main axis. More simply, *squaring nodes* refers to the number of sympodia that have not developed to the flowering stage.

Prior to flowering, squaring nodes is equal to the number of sympodia, as determined by SquareMap. After flowering, squaring nodes is determined by counting NAWF. In relation to first positions on sympodia, all nodes above a first-position white flower will potentially bear a square, while all nodes below the white flower will potentially bear a boll. As boll load increases, development of new main-stem nodes in the plant terminal slows, causing first-position flowers to occur progressively closer to the plant apex. Thus, squaring nodes is an indicator of the fruiting dynamics of the plant throughout the effective fruiting period (Bourland et al., 1992).

INTERPRETATION STANDARDS

A growth curve based on fruiting dynamics is formed when number of squaring nodes from sequential sampling dates are plotted by days after planting (DAP). When interpreting crop growth, the user must consider three standards: 1) square retention, 2) the target development curve and 3) the latest possible cutout date.

Square Retention

High or low square retention can greatly influence the interpretation of a particular growth curve slope. SQUAREMAN summarizes total square shed and shed rate by main-stem nodal position for all first-position squares. Evaluation of square retention is not yet available in BOLLMAN.

Target Development Curve (TDC)

The target development curve assumes that first square appears at 35 days after planting (DAP), first flower at 60 DAP with NAWF = 9.25 and physiological cutout (defined as NAWF=5) at 80 DAP. The apogee of NAWF = 9.25 at first flower was determined by dividing 25 days from square to flower by a 2.7-day vertical squaring interval. Thus, the apogee indicates the number of main-stem nodes added from first square to first flower. TDC is assumed to represent the optimum combination of early maturity and high yield. Actual growth patterns measured in fields can then be compared to the TDC.

Latest Possible Cutout Date (LPC)

Latest possible cutout date is the latest date from which a population of flowers has a high probability of developing into bolls that have acceptable size and quality. COTMAN assumes that 850 heat units (DD60's) are needed for maturation of the last effective boll population. Based on historical weather and a user-defined risk level, LPC is the latest date from which 850 DD60's can be expected to be accumulated prior to a pre-determined harvest completion date. If a field reaches physiological cutout (NAWF=5) prior to LPC date, then end-of-season management is based on crop maturation, and heat units are accumulated from the physiological cutout date. Otherwise, end-of-management is based on weather restraints, and heat units are accumulated from the LPC date.

Factors to Consider When Interpreting Crop Growth Patterns

1) Square retention (high or low).

2) Alignment of curve relative to TDC (left, near or right).

3) Slope of curve relative to TDC (flatter, similar or steeper).

4) Apogee of curve relative to TDC (less, near, above).

5) Change in slope between consecutive sample dates.

6) Physiological cutout date relative to LPC date.

GENERALIZED GROWTH PATTERN INTERPRETATIONS

Alignment of Curve with Slopes Equal to Target

Left of target: Early and/or rapid development of plant structure. If accompanied with high square retention in SQUAREMAN, anticipate high demands for water and nutrients by the developing fruit load. In BOLLMAN, plants may be approaching cutout too early, and stress may reduce yield.

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

Right of target: Delayed and/or slow development of plant structure, often associated with late planting or low seedling vigor. High retention in early fruiting positions should be attained to avoid further delay in maturation and excessive vegetative growth.

Apogee (peak) of Curve at First Flower

Less than target: Stress has reduced plant structure. If stress is not relieved, premature cutout will occur. For optimum yield in situations with a low apogee, curve should flatten or temporarily increase (indicating additional terminal growth) before declining to physiological cutout.

On target: Plants are growing at optimum pace with >10 fruiting branches, which is ample structure for high yields if fruit is retained and an additional five main-stem nodes (non-productive nodes at top of mature plant) are added.

Above target: Plants have attained vigorous nodal development. If accompanied by relatively high fruit retention and development, high yields are likely. Excessive vegetative growth may occur is a good fruit load is not maintained.

Slopes of SQUAREMAN Growth Curve (prior to apogee)

Slope flatter than target: Stressed plant growth, intensity of stress is indicated by flatness of curve and fewer squaring nodes.

Slope steeper than target: Excess plant growth (often associated with fruit shed).

Slope flattens between sampling dates: Plants have become stressed, often associated with moisture stress.

Slope steepens between sampling dates: Plant stress relieved, e.g., rain/irrigation if water deficient.

Slopes of BOLLMAN Growth Curve (after apogee)

Slope flatter than target: Boll load (either number of bolls and/or size of bolls) is low relative to vegetative growth of plant. Maturity is progressively delayed as curve flattens.

Slope steeper than target: Boll load (either number of bolls and/or size of bolls) is high relative to vegetative growth of plant. Steep curve is often associated with small plant structure and/or excessive stress. Time to crop maturity is progressively shortened as slope becomes steeper.

Slope flattens between sampling dates: Reduced rate of boll loading has occurred due to loss of fruit or enhancement of vegetative growth (relieving stress conditions).

Slope steepens between sampling dates: Boll load relative to vegetative growth has increased due to fruit development or stress conditions that slow terminal growth.

Curve ascends after declining past NAWF=5: The ascent (sometimes going above NAWF=5) may indicate second growth of individual plants after they cease terminal growth, or that the sample includes late-maturing plants after the more dominant plants have matured. End-of-season decisions should **not** be dictated by either second growth or the late-maturing plants. Confusion is eliminated by ceasing NAWF sampling when average NAWF drops below 5.0.

SQUAREMAN to BOLLMAN Transition

An inconsistency in number of squaring nodes may be attained during the transition from last SquareMap and first NAWF count. This transition, particularly obvious when last SquareMap and first NAWF are taken on the same day, is related to variation in sampling. Consecutive plants are evaluated by SquareMap, while only plants with first-position white flowers are included in the NAWF sample. Thus, only plants that have initiated flowering, rather than all plants, are sampled for NAWF during early initiation of flowering.

SquareMap squaring nodes relatively same as NAWF: Relatively uniform plants within the field, such that most plants have initiated flowering near the same time.

NAWF>SquareMap squaring nodes: Non-uniform plant population. Early flowering plants are more dominant and vigorous than the rest of the plant population. The late, less-dominant plants can cause flattening or ascent of the BOLLMAN curve as they begin to flower.

NAWF<SquareMap squaring nodes: Non-uniform plant population. Early flowering plants are less dominant and vigorous than the rest of the plant population. Bimodal fruiting curve may occur as the more-dominant, late plants begin flowering.

INTERPRETATION EXAMPLES

The following 16 curves provide a range of likely scenarios that may be experienced with crop growth patterns generated by COTMAN. Four SQUAREMAN curves are compared to TDC, a likely cause is proposed, and actions for high and low square retention situations are suggested (Fig. 1). BOLLMAN curves include situations in which ascents of the curves derived by SQUAREMAN were on target (Fig. 2), above target (Fig. 3) and below target (Fig. 4). Each BOLLMAN curve is described, and a likely cause is proposed. Comparison with an arbitrarily established LPC date is used to determine whether crop- or weather-oriented rules would be used, and physiological cutout date, i.e., days to NAWF = 5, is determined. Finally, a production efficiency index, a subjective appraisal of potential yield and production risks, is assigned to each curve. Rather than attempting to predict yields, this index should serve as a signal of growth pattern situations that are likely to be problematic.

FINAL REMARKS

COTMAN provides a dynamic, interactive process to evaluate plant growth development throughout the fruiting period. These generalizations and examples should help users to better understand this dynamic process. The SQUAREMAN computer program provides 24 sets (8 of these are represented in Fig. 1) of decisions rules that are triggered by particular combinations of position relative to TDC, slope and square retention. The BOLLMAN program provides guidelines on specific end-of-season decisions and relative crop maturity.

Specific knowledge of growing conditions, including planting date, plant density, cultivar, soil, weather, pest problems, etc., within a field will greatly enhance the ability of the user to interpret growth curves. Each of these factors directly and indirectly (interacting with other factors) influences plant growth and development. A better understanding of these influences will provide insight for remedying in-season problems and minimizing risks associated with factors that cannot be adjusted within the season. The growth curve provides a composite picture of all direct and indirect influences that affect plant development. With experience, the user should be able to quickly evaluate and properly react to the growth curve.

ACKNOWLEDGMENTS

LITERATURE CITED

Bourland, F.M., D.M. Oosterhuis and N.P. Tugwell. 1992. Concept for monitoring the growth and development of cotton plants using the main-stem node counts. J. Prod. Agric. 5:532-538.

Oosterhuis, D.M, F.M.Bourland, N.P. Tugwell and M.J. Cochran. 1996. Terminology and concepts related to the COTMAN crop monitoring system. Ark. Agric. Exp. Sta. Special Report 174.
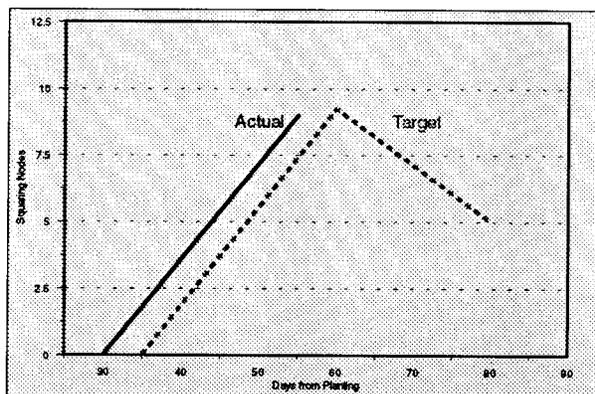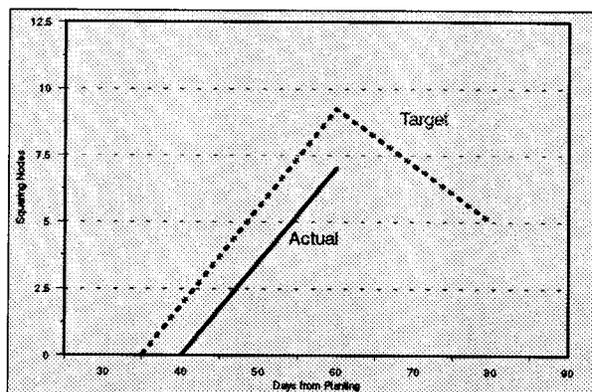
Description	Slope equal to target but nodal development is early
Likely cause	Optimum conditions after planting, usually accompanied by low first fruiting node
Action:	
High retention	Anticipate very high fruit demands
Low retention	Anticipate relatively low demands, monitor & control vegetative growth

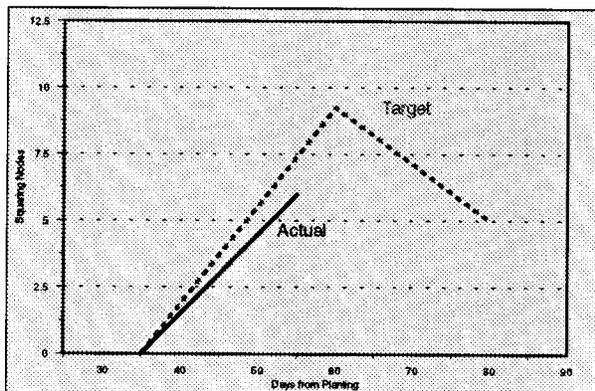| Description	Slope equal to target but nodal development delayed
Likely cause	Slow emergence (check seedlings for root damage); 1st fruiting node at main-stem node 7 or higher
Action:	
High retention	Maintain growth rate to achieve acceptable maturity
Low retention	Remedy as quickly as possible to avoid late maturity

Description	Slope flatter than target
Likely cause	Chronic plant stress due to insufficient water, nitrogen deficiency, fine-textured soil, etc.
Action:	
High retention	Immediately relieve stress to avoid premature cutout
Low retention	Less critical to immediately relieve stress; continue to monitor plant growth and fruit retention
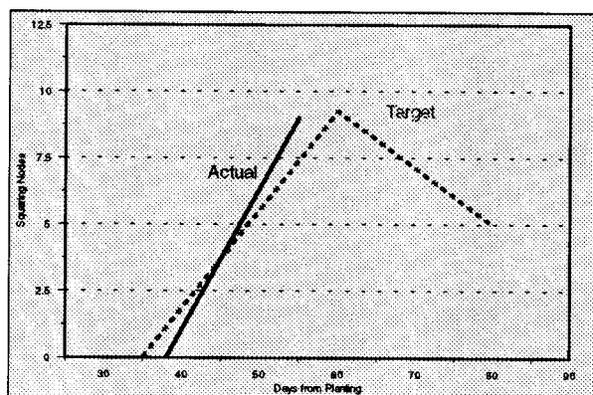
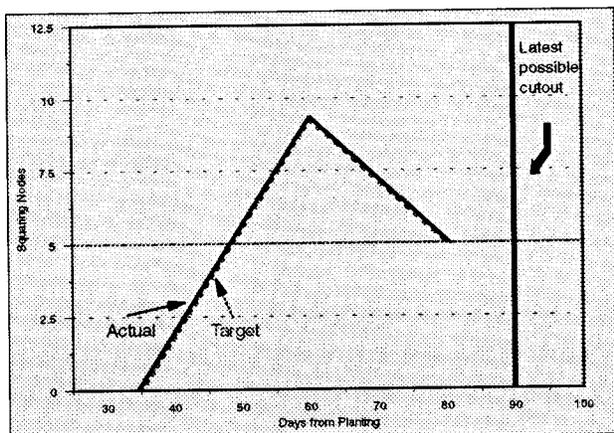| Description	Slope steeper than target after slow start
Likely cause	Loss of fruit accompanied by good growing conditions
Action:	
High retention	Not likely to occur; monitor & control vegetative growth
Low retention	Control cause of fruit loss, monitor & control vegetative growth

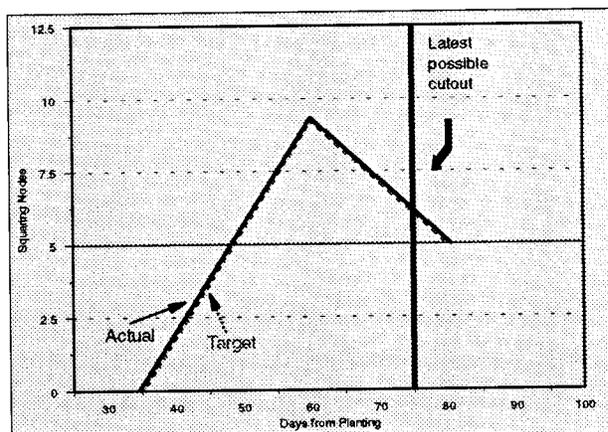Fig. 1. Examples of crop growth curves derived from SQUAREMAN.

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| Description	On-target fruiting pattern attaining physiological cutout prior to latest possible cutout date
Likely cause	Optimum combination of factors producing early maturation and yield
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	80 DAP
Prod. Eff. Index	100% TDC

Description	On-target fruiting pattern, but physiological cutout after latest possible cutout date
Likely cause	Late planting
End-of-season mgt.	Weather-oriented rules
Physiol. Maturity	80 DAP
Prod. Eff. Index	90% TDC
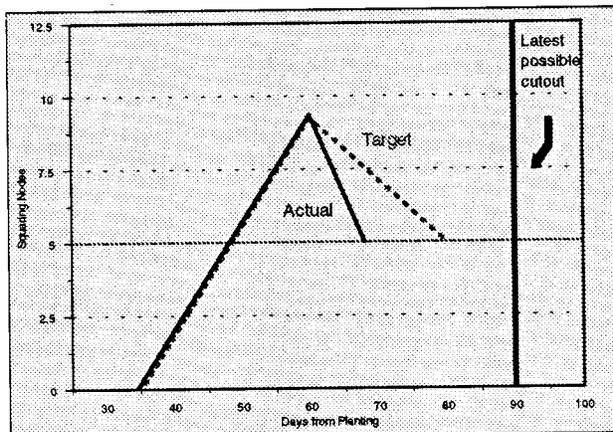
Description	Rapid decline in NAWF
Likely cause	Severe chronic stress, for example, water deficit
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	68 DAP
Prod. Eff. Index	75% TDC
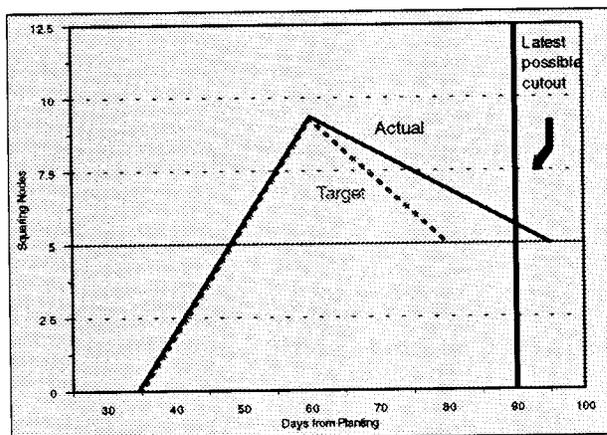
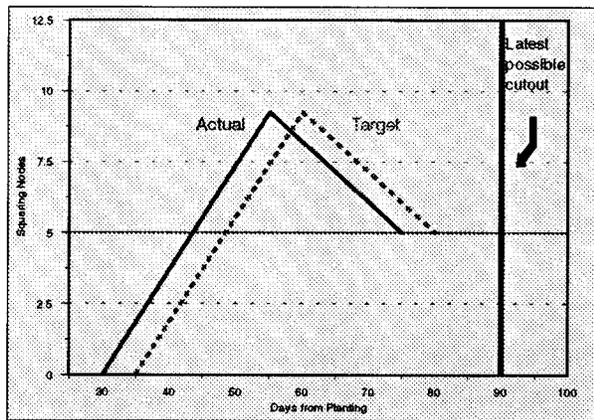| Description	Slow decline in NAWF
Likely cause	Loss of bolls to physiological shed and possibly insects; excess vegetative growth
End-of-season mgt.	Weather-oriented rules
Physiol. Maturity	95 DAP
Prod. Eff. Index	90% TDC

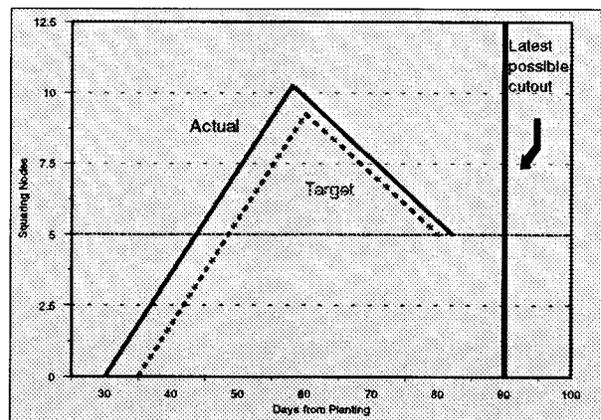Fig. 2. Examples of BOLLMAN curves when SQUAREMAN was on target.

| Description	Early fruiting with slope similar to target
Likely cause	Early plant and fruit development with fruiting initiated on low main-stem node
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	75 DAP
Prod. Eff. Index	105% TDC

| Description	Early and extended fruiting pattern with slopes similar to target, but higher apogee
Likely cause	Vigorous early growth with satisfactory boll retention, followed by good growing conditions
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	82 DAP
Prod. Eff. Index	110% TDC
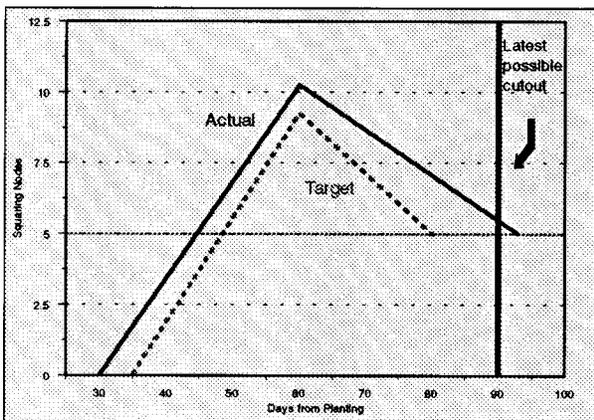
Description	Prolonged fruiting pattern with slow NAWF decline
Likely cause	Vigorous early growth with relatively low boll retention
End-of-season mgt.	Weather-oriented rules
Physiol. Maturity	93 DAP
Prod. Eff. Index	95% TDC
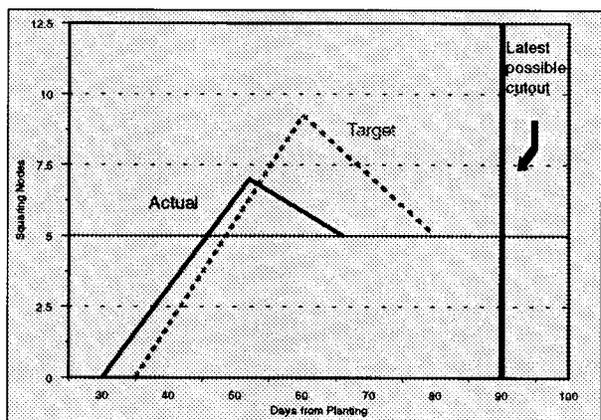
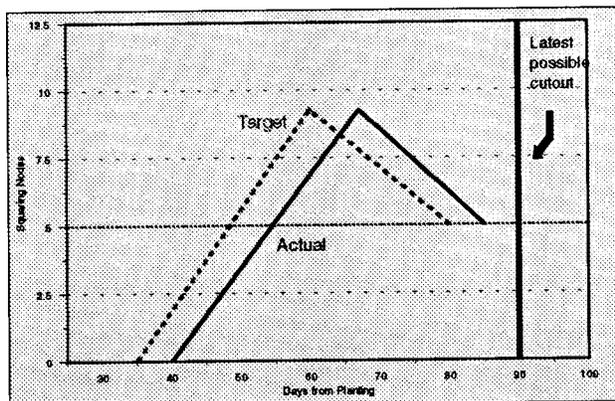| Description	Very early initiation of flowering followed by premature cutout
Likely cause	Low first fruiting node followed by high boll retention and chronic stress
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	65 DAP
Prod. Eff. Index	70% TDC

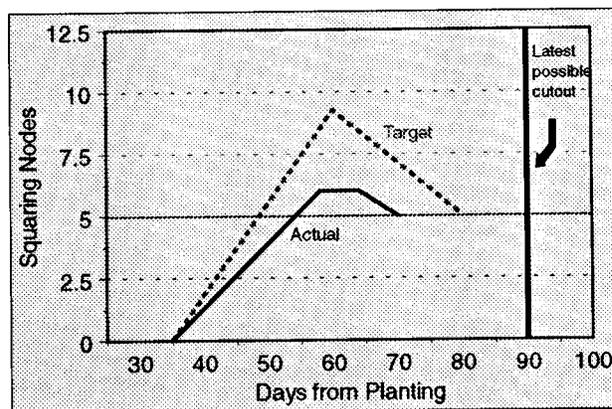Fig. 3. Examples of BOLLMAN curves when SQUAREMAN was above target.

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| Description	Optimum growth pattern, but delayed squaring node initiation
Likely cause	Adverse conditions causing slow emergence or conditions causing high first fruiting node
End-of-season mgt.	Crop-oriented
Physiol. Maturity	85 DAP
Prod. Eff. Index	95% TDC

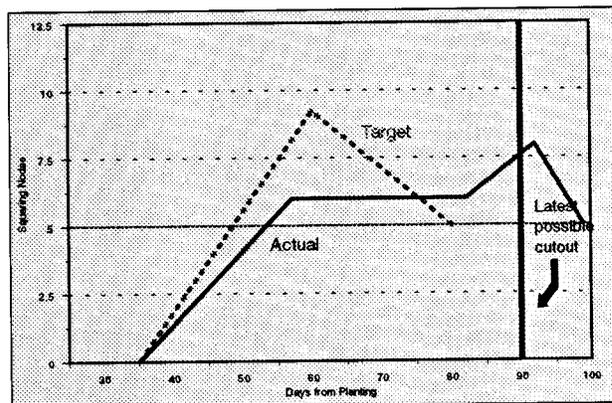| Description	Slow development of squaring nodes, low squaring nodes at first flower and premature cutout
Likely cause	Chronic stress through-out fruiting period
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	70 DAP
Prod. Eff. Index	50% TDC
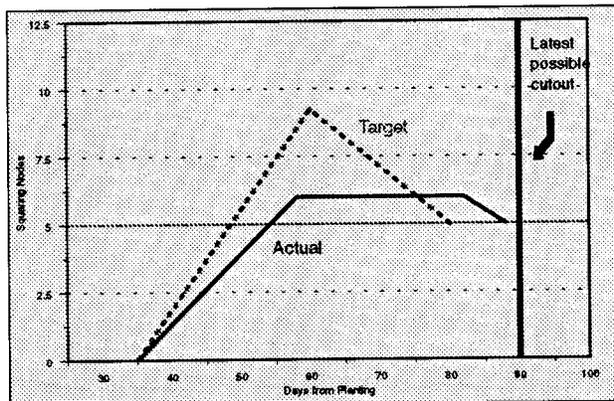
Description	Slow development of squaring nodes, low squaring nodes at first flower and delayed cutout
Likely cause	Early & mid-season stress, followed by sustained vegetative and fruit development
End-of-season mgt.	Crop-oriented rules
Physiol. Maturity	88 DAP
Prod. Eff. Index	85% TDC

Description	Slow development of squaring nodes; low apogee at first flower, and excess late-season growth
Likely cause	Early & mid-season stress, followed by relief of stress - often accompanied by low fruit retention
End-of-season mgt.	Weather-oriented rules
Physiol. Maturity	98 DAP
Prod. Eff. Index	80% TDC

Fig. 4. Examples of BOLLMAN curves when SQUAREMAN was below target.