

CAN PLANT-BASED MOISTURE SENSING IMPROVE IRRIGATION SCHEDULING AND WATER USE EFFICIENCY? PRACTICAL COTTON REMOTE SENSING PROJECT, ISRAEL 2013

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Abstract

Decision-making is a vital part of the daily work routine in each and every crop, all the more so in an irrigated and intensive crop such as cotton. Phytech's monitoring and information system for decision-making takes plant management one step further. Data from daily and weekly measurements provide immediate and dynamic information on plant response to any change in the plant-soil-climate interface and thus provide us with real-time early warnings of unwanted plant interface changes.

Phytech system consists of three main data components:

1. Soil moisture and salinity.
2. Climate data.
3. Stem daily growth and contraction.

The heart of the Phytech monitoring system is the comparison of the daily stem diameter changes to the existing reference guide lines. The information system that we present here was tested successfully in high-yield intensive cotton production fields.

Irrigation control done at the vegetative growth stage is based on the daily height growth (cm/day) of the stem. An excellent correlation between the growth of stem height and the growth of the stem diameter was established. A recommended curve for daily stem growth is based on optimal values that are needed to be kept the day before the next irrigation.

Irrigation control done at the reproductive stage is based on the leaf water potential (bar). There is an excellent correlation between the leaf water potential and the maximal daily contraction (MDC) of the stem. Based on this relationship we have developed the recommendations for an irrigation schedule by monitoring the daily maximal contraction of the stem as measured by the stem dendrometer sensor.

A recommended curve for stem maximal daily contraction (MDC) refers to the maximum values that are needed to be kept the day before the next irrigation.

In summary, the information system provides reliable daily data, optimal reference curves give a good basis for directing the irrigation schedule and the amount of water required for the plants in all crop stages.

Introduction

Decision-making is a vital part of the daily work routine in each and every crop, all the more so in an irrigated and intensive crop such as cotton. Phytech's monitoring and information system for decision-making takes plant management one step further. Data from daily and weekly measurements provide immediate and dynamic information on plant response to any change in the plant-soil-climate interface and thus provide us with real-time early warnings of unwanted plant interface changes.

Working with information systems that provide continuous online data which is available at any time is the future of irrigated crop management. The system sensors provide reliable available information which translates into real action thresholds in cotton high-yield production irrigation. The information system that we present here was tested successfully in the 2012-13 seasons in high-yield intensive cotton production fields in all growing regions of Israel.

A project was set up together with the Israel Cotton Board as the grower's representative to enable growers to try out the monitoring system accompanied by professional agronomic consultancy. During the season the growers had weekly meetings as well as field visits which helped them learn to translate information coming from the system into valuable "know-how" for adjusting decisions on irrigation scheduling from week to week.

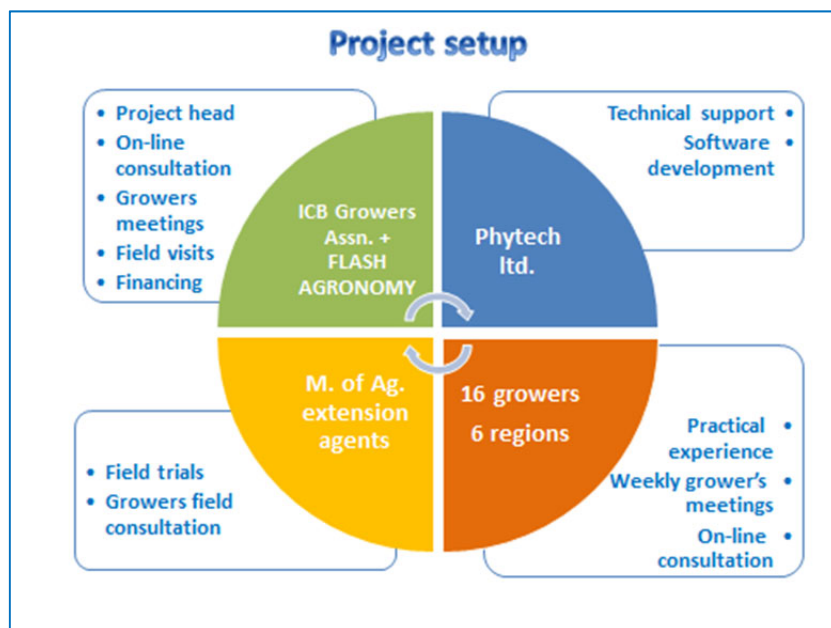


Figure 1: Israel 2013 season project setup.

Why does the stem shrink and swell?

The flow of water from the soil, through the plant and into the atmosphere is driven by water potential gradients between each component of the system. Water moves from the soil to the roots and then up the plant stem in the xylem, which is considered to be bundles of hollow, dead cells. Surrounding the xylem are living cells, including cambial and phloem tissues.

There are small flow paths between these living tissues and the xylem, but the connections are limited, causing resistances to flow that vary among plants species. As transpiration losses from leaves increase in the early morning hours, some water moves out of the living tissues and into the xylem in response to the water potential gradients that develop. Because the cell walls of the living tissues are flexible, this movement is assumed to cause the stem to shrink. As transpiration slows in the late afternoon, the potential gradient reverses and some water flows back from the xylem to the living tissues, causing the stem to swell.

Under deficit irrigation, transpiration during most of the day exceeds root water supply, and greater water potential gradients develop between the xylem and living tissue. The rate of water flow between these tissues then increases, causing greater stem shrinkage. Stem diameter fluctuations occur in response to the potential gradients within the stem, which reflect the balance between plant water supply and demand. Therefore there should be a close association between the daily evolution of plant water status and stem diameter oscillations, which could be used instead of the conventional plant water status measurements for irrigation management.

Why monitor stem diameter in cotton?

- Easy installation.
- Very high sensitivities to irrigation and climatic conditions at all physiological stages of plant development.
- High correlation with water status plant indicators (leaf water potential, evapotranspiration).
- Clear description and representation of physiological processes through water content indicators of plant (maximum daily contraction, daily growth, stem diameter water potential).

Materials and Methods

Phytech system consists of three main data components:

1. Information on soil moisture and salinity.
2. Climate data of temperature, humidity, solar radiation, wind, and calculated evapotranspiration and air saturated vapor pressure deficit.
3. Information on the behavior of the stem, daily growth and daily contraction.

The heart of the Phytech monitoring system is the comparison of the daily stem diameter changes to the existing reference curves.

Results and Discussion

Stem diameter growth curve:

Cotton production is divided into three major growth stages:

- Stage I - The vegetative stage ;
- Stage II – The reproductive stage, boll development ;
- Stage III – The reproductive stage, boll maturing and opening.

Each stage relies on important plant characteristics that are measurable and irrigation is controlled accordingly. Measurements of the stem diameter (Figure 2) show these characteristics in the three growth stages. Each stage relies on existing plant optimal growth references when making irrigation decisions:

- In stage I irrigation control is done according to the stem height daily rate of growth ;
- In stage II irrigation control is done according to leaf water potential ;
- In stage III irrigation control is done according to leaf water potential and soil moisture measurements.

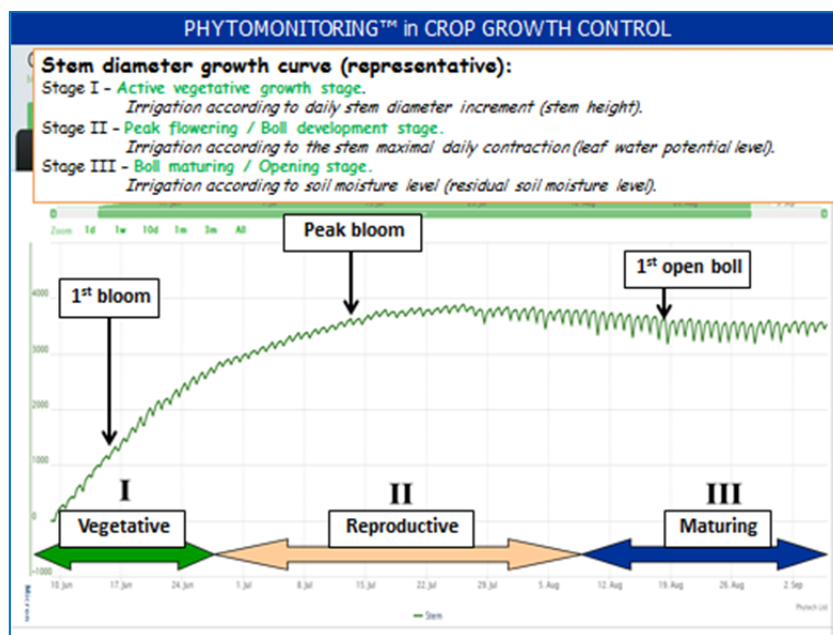


Figure 2: Typical stem diameter seasonal growth curve.

Comparison of daily stem elongation rate to daily diameter growth rate:

Irrigation control done at the vegetative growth stage (Stage I) is based on the daily rate of stem elongation growth (cm/day), and according to the optimal reference curve developed over the years. Based on the results from our experiments, excellent correlation was established between stem elongation and the growth of the stem diameter. This chart shows the correlation between the two indices. Based on this relationship we have developed the recommendations for controlling irrigation by monitoring the daily growth rate of **stem diameter** as measured by the stem dendrometer sensor (Figure 3).

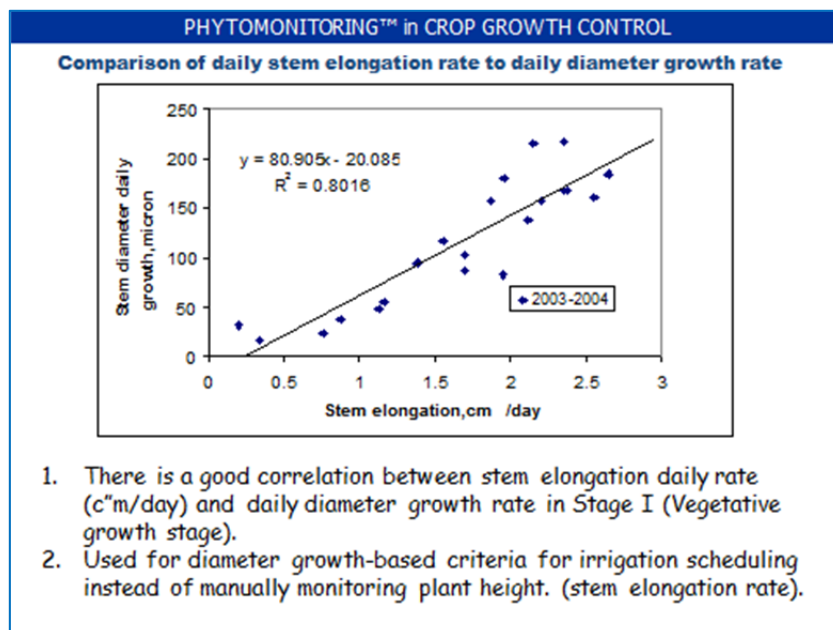


Figure 3: Comparison of daily stem elongation rate to daily diameter growth rate, irrigation experiments, 2003-4.

Recommended values for optimal stem diameter daily growth for cotton in vegetative stage:

A recommended curve for daily stem growth in the vegetative growth stage based on past experiments with data obtained from the plant stem. The curve refers to the optimal values needed to be kept the day before the next irrigation along the vegetative period (Figure 4).

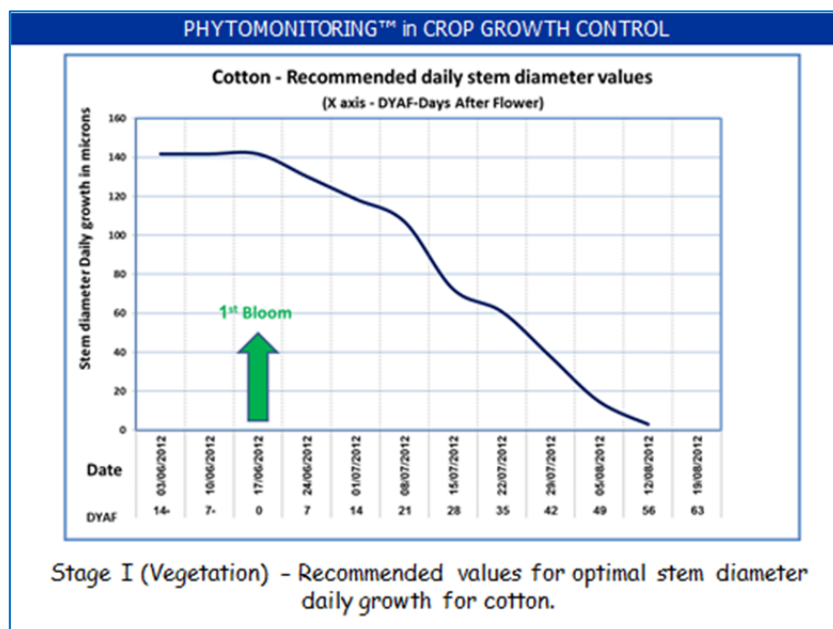


Figure 4: Recommended values for optimal stem diameter daily growth for cotton in the vegetative stage.

A practical example of a field from the 2013 season shows how actual high production field behavior is well matched to the reference curve in the vegetative stage (Figure 5).

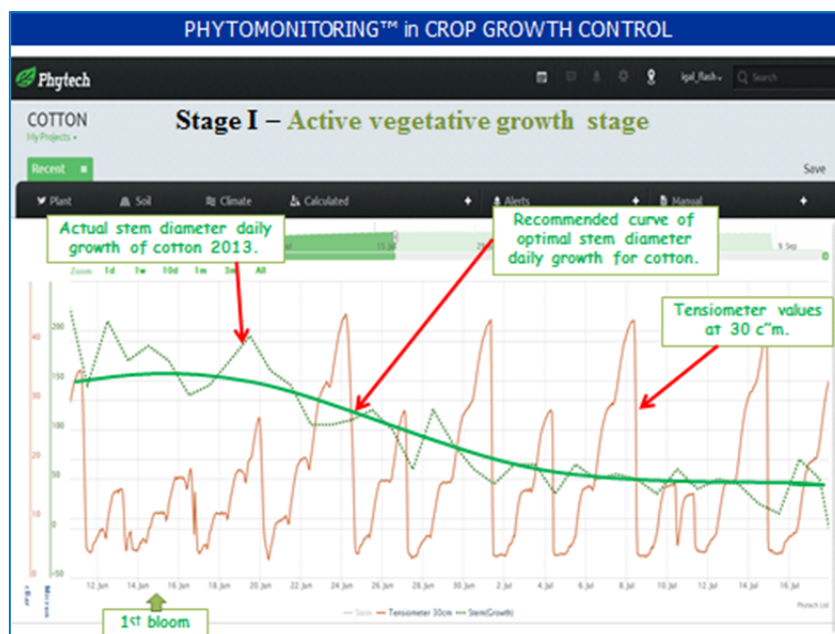


Figure 5: Crop stage I of field example for typical stem diameter seasonal growth compared to the reference curve.

Comparison of leaf water potential (noon daytime) and stem Maximal Daily Contraction (MDC) at the reproduction stage:

Irrigation control done at the reproductive growth stage (Stages II, III) is based on the noon time leaf water potential (bar) according to optimal curve developed over the years. Based on the results from our experiments, there is excellent correlation between the leaf water potential (as measured by Scholander pressure chamber at noon) and the maximal daily contraction (MDC) of the stem.

The chart shows the correlation between the two indices (Figure 6). Based on this, we have developed the recommendations for the irrigation schedule by monitoring the daily maximal contraction of the stem as measured by the stem dendrometer sensor.

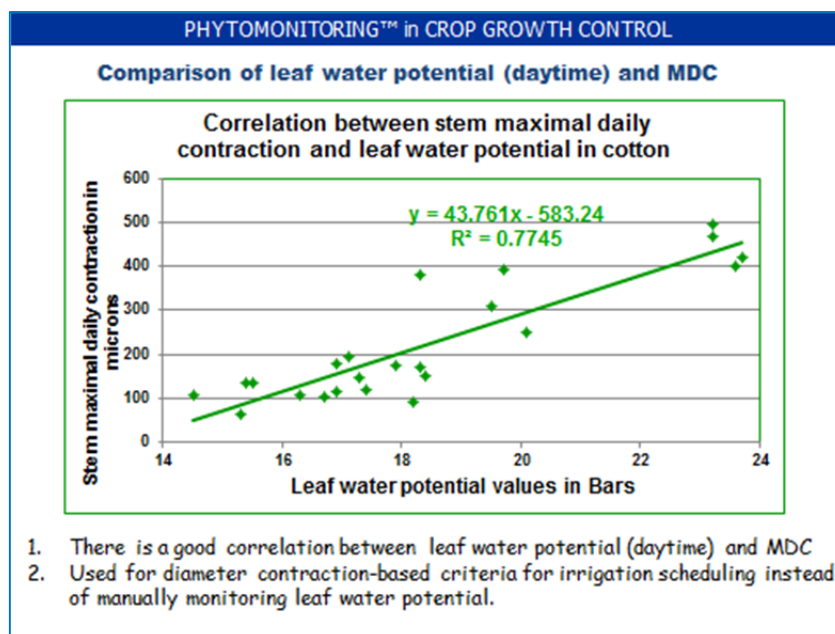


Figure 6: Comparison of leaf water potential (noon daytime) and stem Maximal Daily Contraction (MDC) in the reproduction stage.

Based on this relationship we have developed the recommendations for the irrigation schedule by monitoring the daily maximal contraction of the stem as measured by the stem dendrometer sensor.

Maximum daily stem contraction recommendations based on past experiments allows daily work to be conducted with the data obtained from the plant stem (Figure 7). The curve refers to the maximum values needed to be kept the day before the next irrigation in the reproductive period.

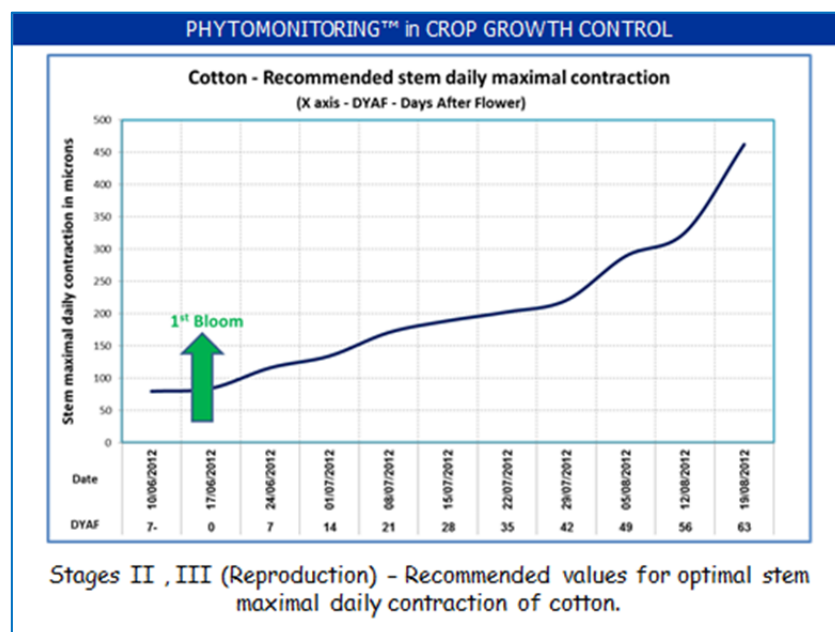


Figure 7: Recommended stem maximal daily contraction optimal curve in the reproductive stage (MDC)

A practical example of a field from the 2013 season shows how actual field behavior is well matched to the reference curve in the reproductive stage (Figure 8).

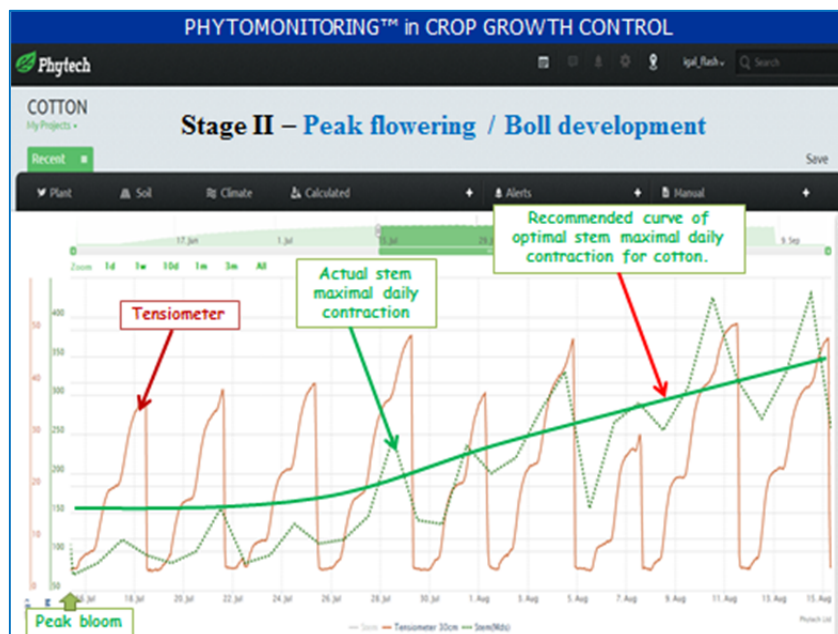


Figure 8: Crop stage II of field example for typical recommended stem maximal daily contraction as compared to the recommended reference line.

Conclusions and Summary

Using stem diameter monitoring in cotton:

The information system provides reliable daily data, optimal reference curves give a good basis for directing irrigation schedule and amount of water required for the plants in all crop stages.

Our results demonstrate that it is feasible to develop an irrigation schedule based solely on stem diameter growth and contraction signals, which may be tailored to any desired stress pattern and be operated in full automation and alerts with the appropriate software.

The Phyttech monitoring system is:

- Easy to install.
- Very high sensitivity to plant water conditions at all physiological development stages.
- High correlation with plant water status indicators (leaf water potential, evapotranspiration).
- Recommended stem daily growth values at main vegetative growth stage.
- Recommended stem daily maximal contraction potential at boll development and maturing stages.
- Day to day easy monitoring, plant-soil-climate water status with reliable recommended indicators.

In the future, alert-based monitoring system will allow grower access to simple and reliable on-line information for irrigation schedule changes (Figure 9).

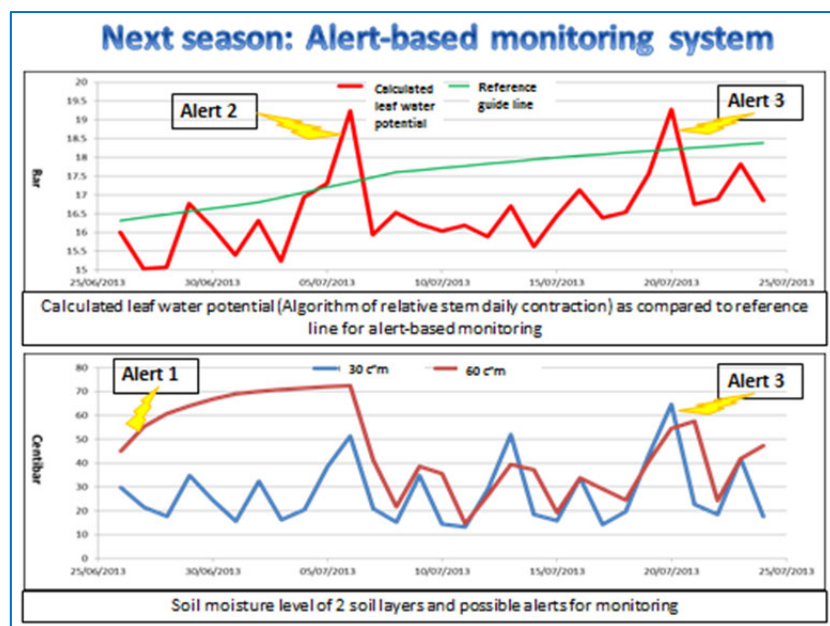


Figure 9: Example of the future applicable alert-based monitoring system based on stem diameter and soil moisture data.

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