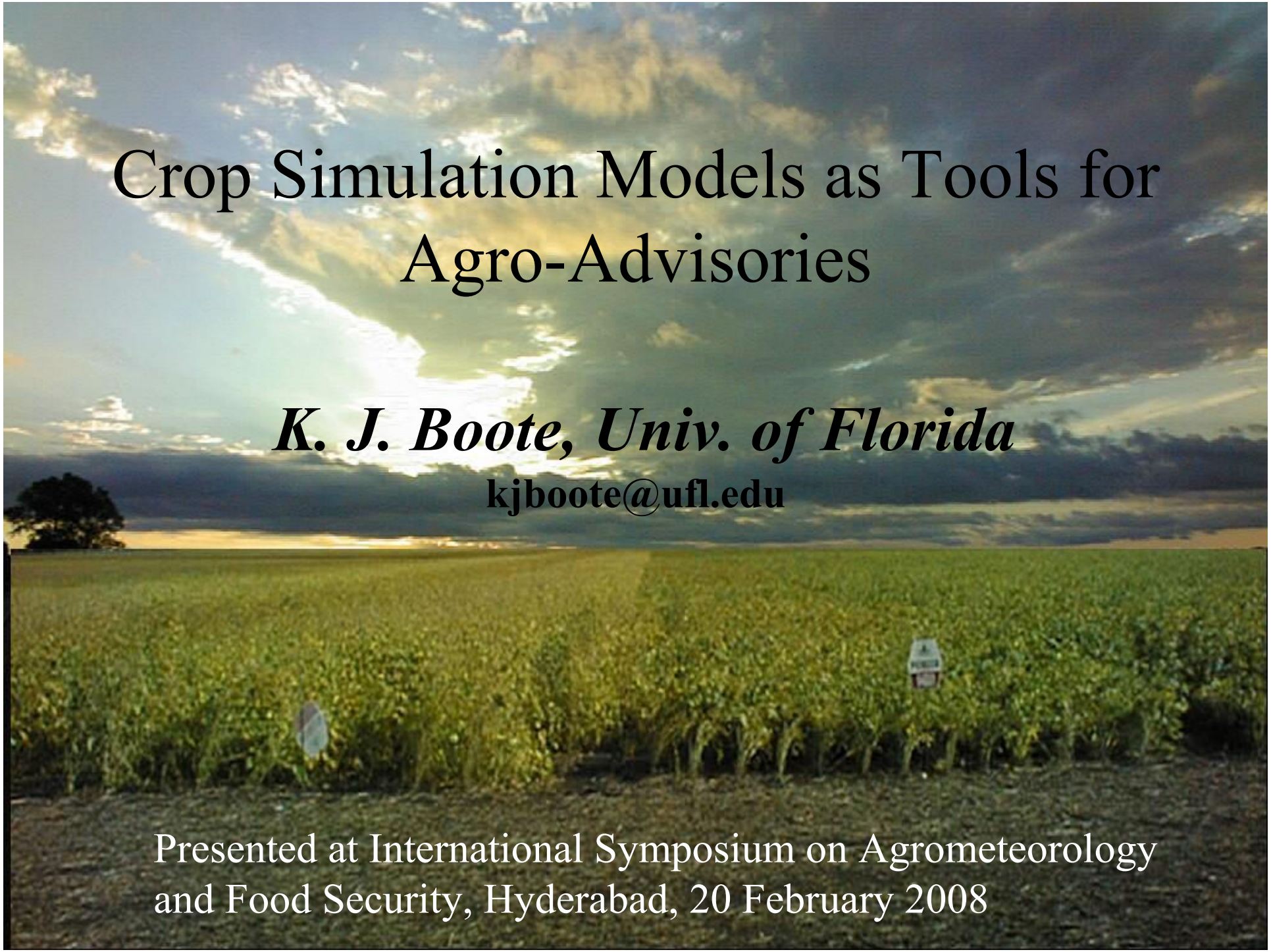


Crop Simulation Models as Tools for Agro-Advisories

K. J. Boote, Univ. of Florida

kjboote@ufl.edu

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Crop Models as Application Tools:

Strategic (Pre-season with historical weather)

- Predict outcomes (yield, irrigation demand, N leaching) under different management, climate and soil conditions
- Analyze what occurred in the past
- Predict what will occur in the future
- Evaluate ways to improve or optimize practices under different scenarios

In-Season Decisions

- Use real weather up to today, then short-term forecast, then ENSO forecast or historical.
- Run model, with or without the altered management.

CROPGRO and CERES Models

- These models are part of the DSSAT (Decision Support System for Agrotechnology Transfer).
- Predict growth and development of grain legumes and cereals, respectively.
- Process-level: Simulate inputs, losses, & balance of C, N, and H_2O.
- Requires information about site, management
  - Daily weather
  - Soil characteristics
  - Management
  - Cultivar traits
- Based on understanding of crop-soil-weather relationships
- Can be used to perform “what if?” experiments

Knowledge Embedded in Crop Models

- Crop models capture much of what we know about crop growth response to temperature, solar radiation, rainfall, daylength, soil traits, and crop management.
- Can be used to perform "what if?" experiments
- Use to define climatic potential yield for a region. Define the crop response to sowing date, cultivar choice, irrigation, N fertilization, etc. BUT do not address pests or soil nutrients other than N.
- Requires that the models accurately predict responses to N fertilization, soil water balance, cultivar, and management factors.

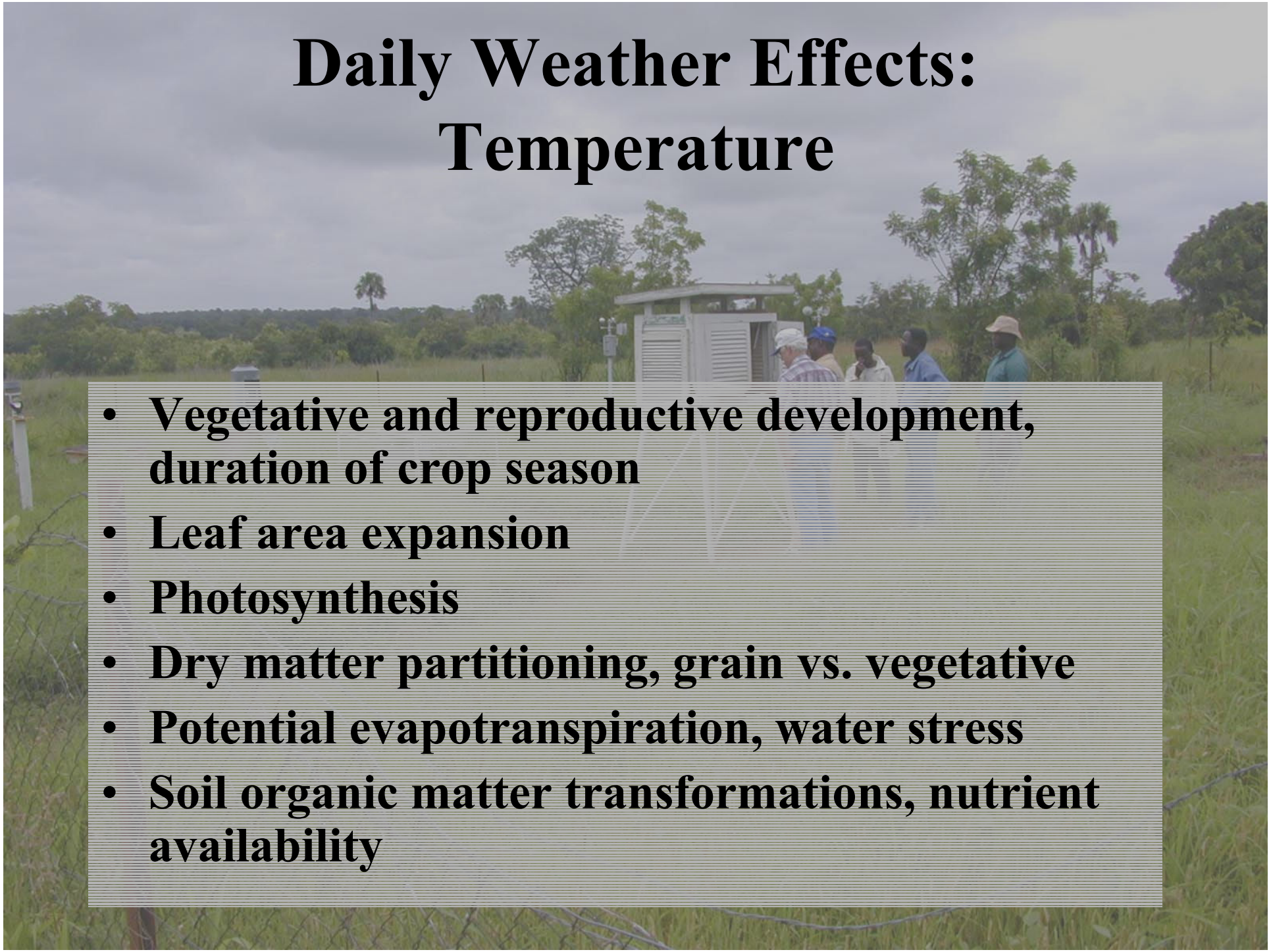
Climate and Agriculture

- **Climate is the major driver of agriculture**
  - **What to plant**
  - **Where to plant it**
  - **How to manage it**
- **Soils play a major role**
- **Other factors**
  - **Human needs, market availability & access, etc.**

Weather Makes Farming a Risky Business

- Seasonal onset and termination of rainfall
- Excess Rainfall, Flooding
- Drought
- Freezes
- Wind (Hurricanes, Tornados)
- Seasonal variations in Temperature, are not as dramatic, but have major impact
- Seasonal variation in Solar Radiation
- Daylength (time of year)

Daily Weather Effects: Temperature



- Vegetative and reproductive development, duration of crop season
- Leaf area expansion
- Photosynthesis
- Dry matter partitioning, grain vs. vegetative
- Potential evapotranspiration, water stress
- Soil organic matter transformations, nutrient availability

Daily Weather Effects:

Rainfall

- Soil Water Availability
- Water stress and its effects on growth processes (both water deficit stress and anaerobic stress)

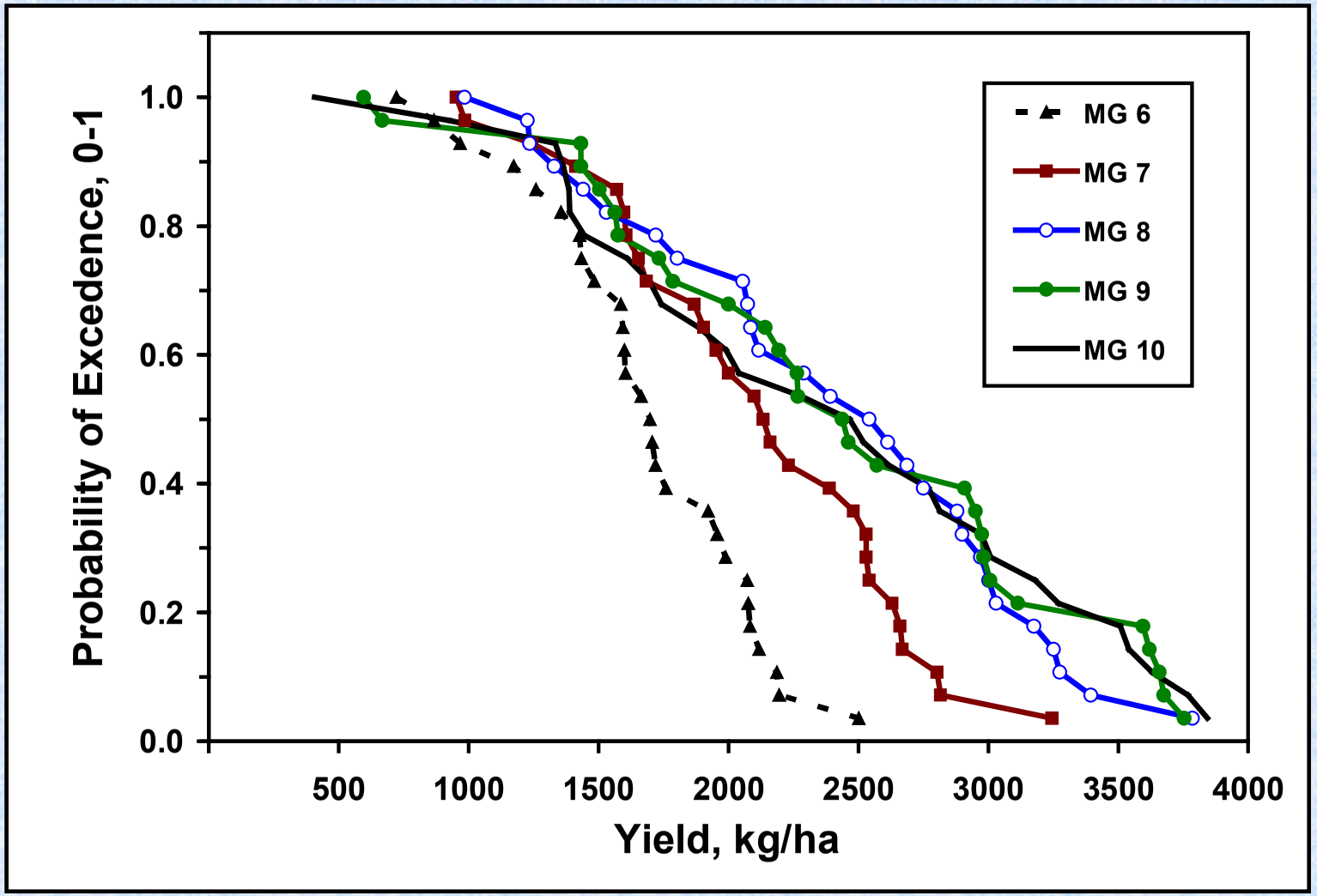
Solar Radiation

- Photosynthesis
- Potential evapotranspiration, thus actual evapotranspiration and plant water stress
- Temperature in soil & canopy (microclimate)

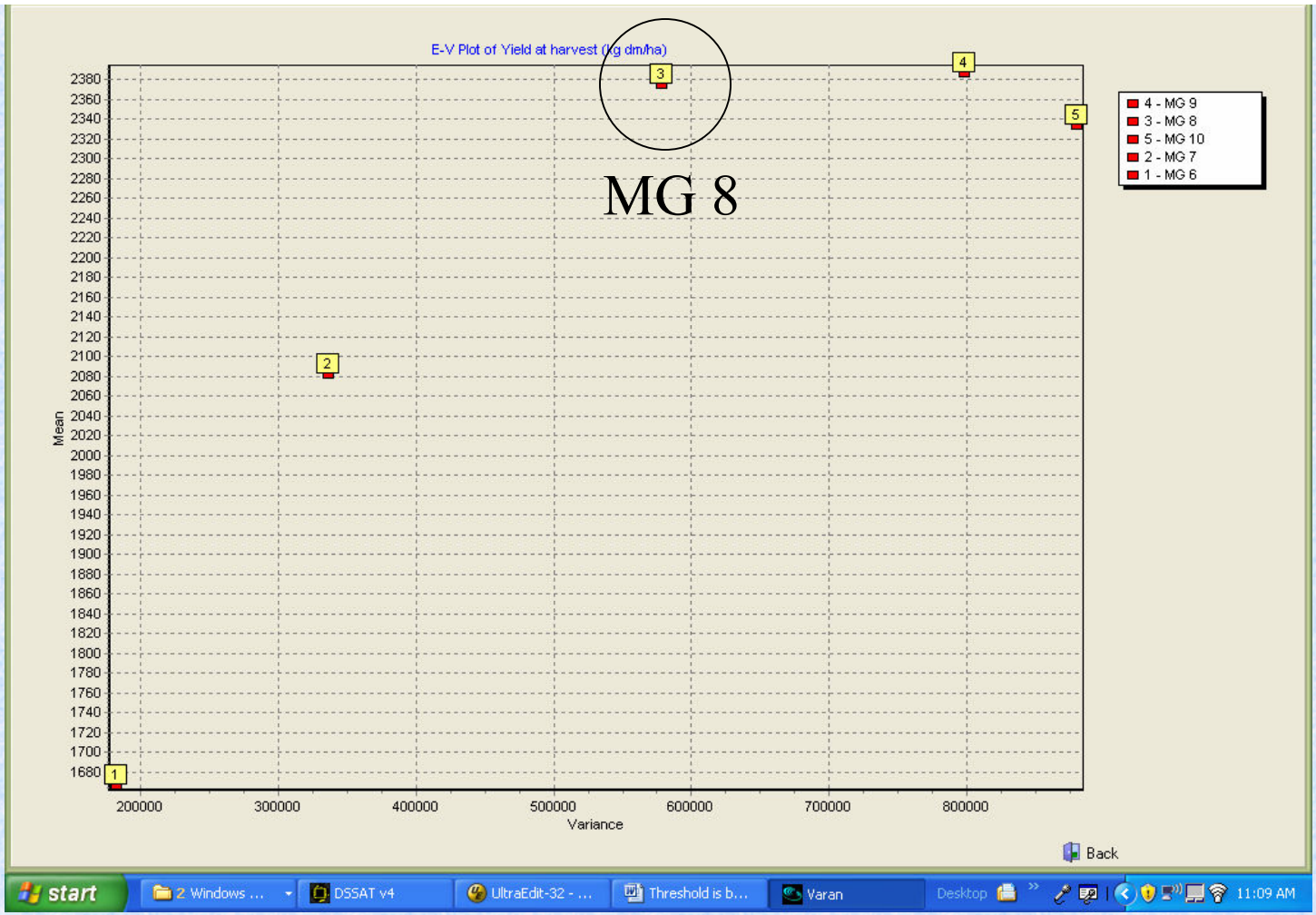
DSSAT V4.0 Models Used to Hypothesize Improved Management

- Soybean and maize for Alfisol soil, with 28 years of weather at Hyderabad.
- Groundnut on shallow loamy sand, with 32 years of weather at Anantapur.
- Evaluated response to sowing date, MG (soybean only), N fertilization (maize only), & irrigation
- Initial soil water at 50% FC, auto-plant when soil water >70%, irrigate when 40% of FC is left in top 40 cm. Initial N at 25 kg/ha averaged over profile depth.
- Soybean at 25 plants/m2, maize at 6 plants/m2, groundnut at 28 plants/m2.

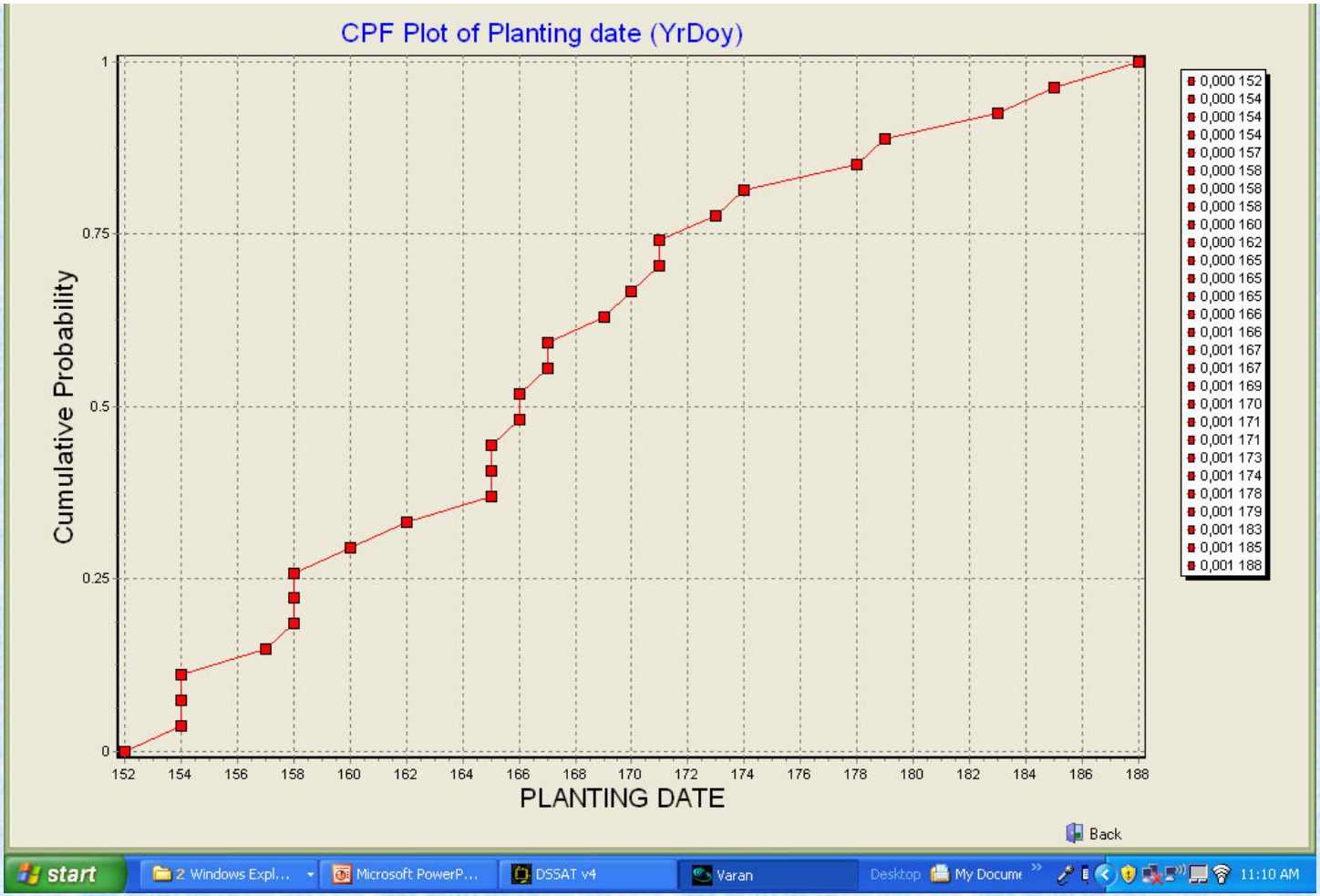
Probability of Attaining a Given Yield for Maturity Group 6, 7, 8, 9, 10 Soybean under Rainfed Conditions for Early Sowing at Patancheru, India



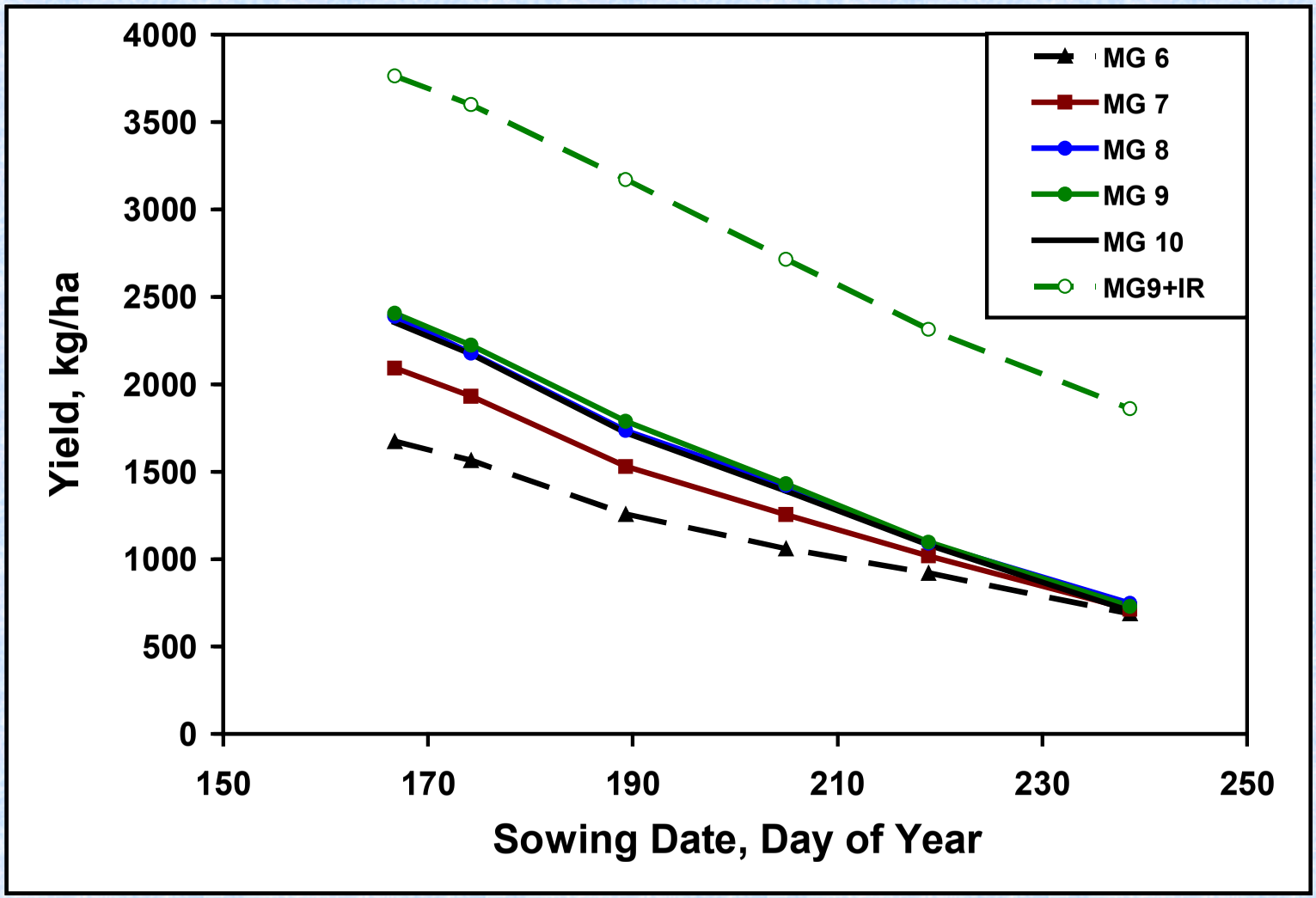
Variance Analyses (Mean Geni): Mean yield versus variance shows MG 8 was best choice, having nearly highest yield, but lower variance than MG 9 or 10.



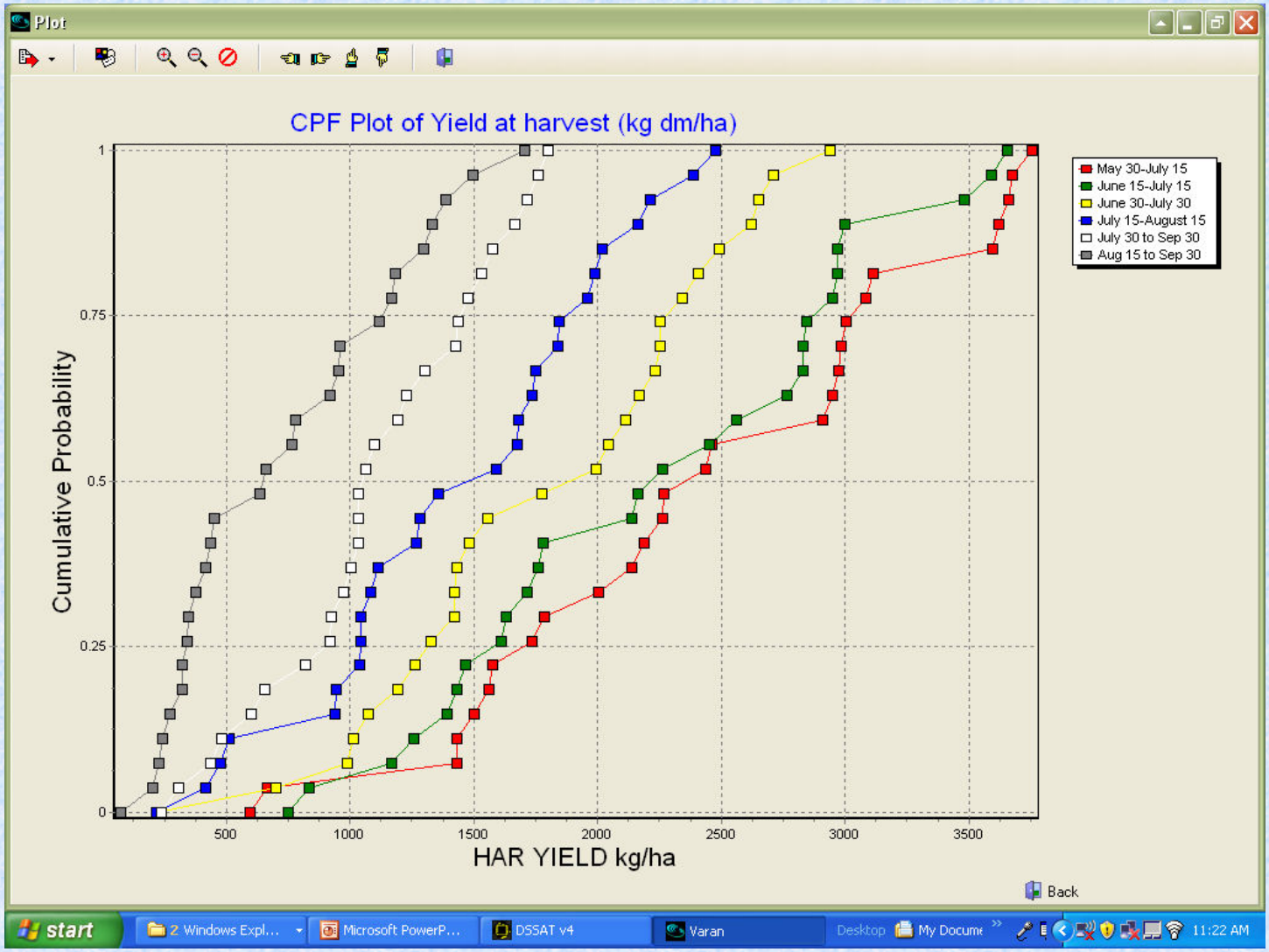
Example of early sowing window, dependent on rainfall to give >70% FC at Patancheru. Window was May 15 to July 15 (135-196). Actual sowing ranged from 152 to 188 over 28 years, mean of 167.



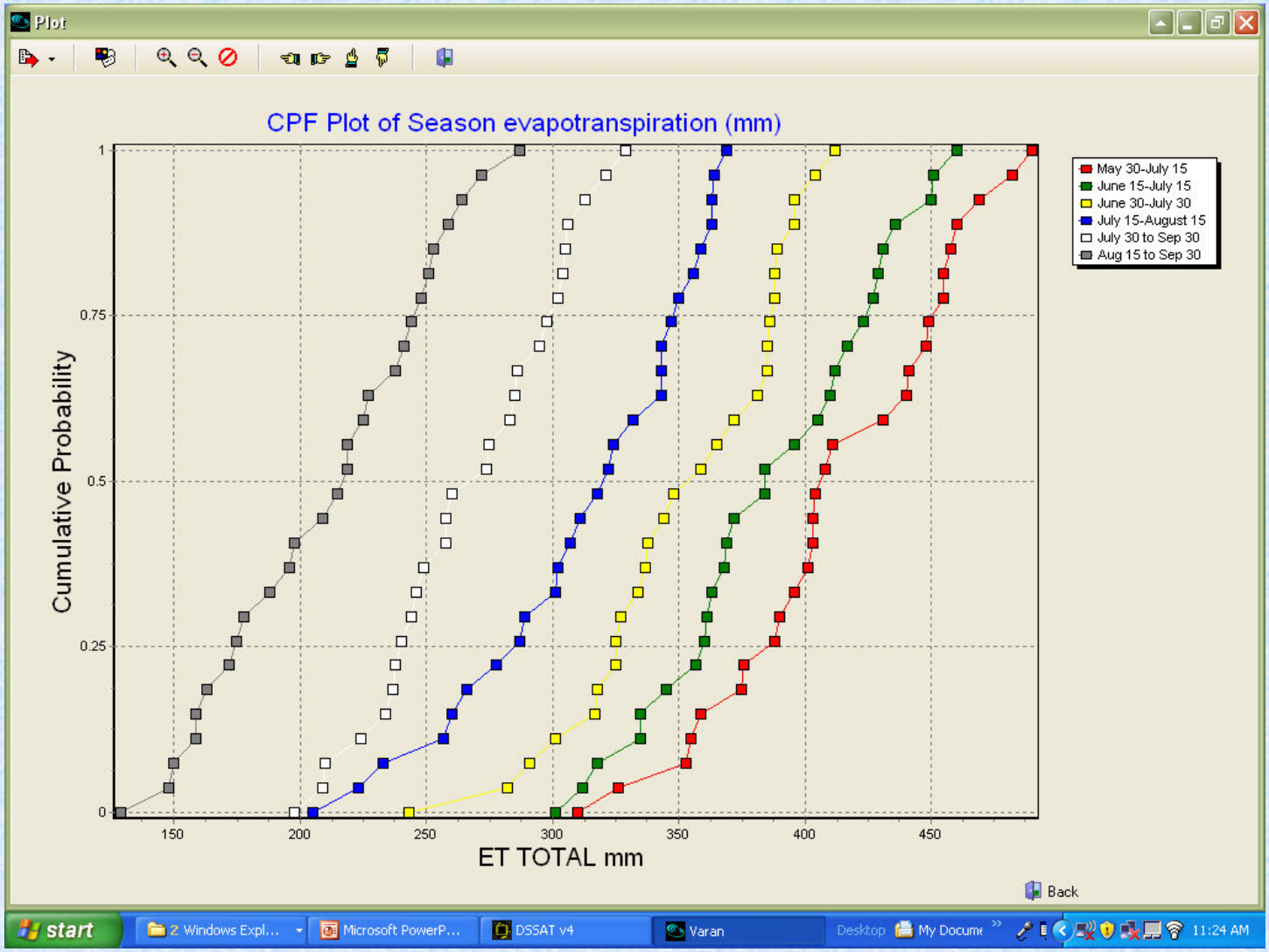
Soybean yield response to “mean” sowing date for five MG under rainfed and irrigated conditions, averaged over 28 weather years at Patancheru, India.



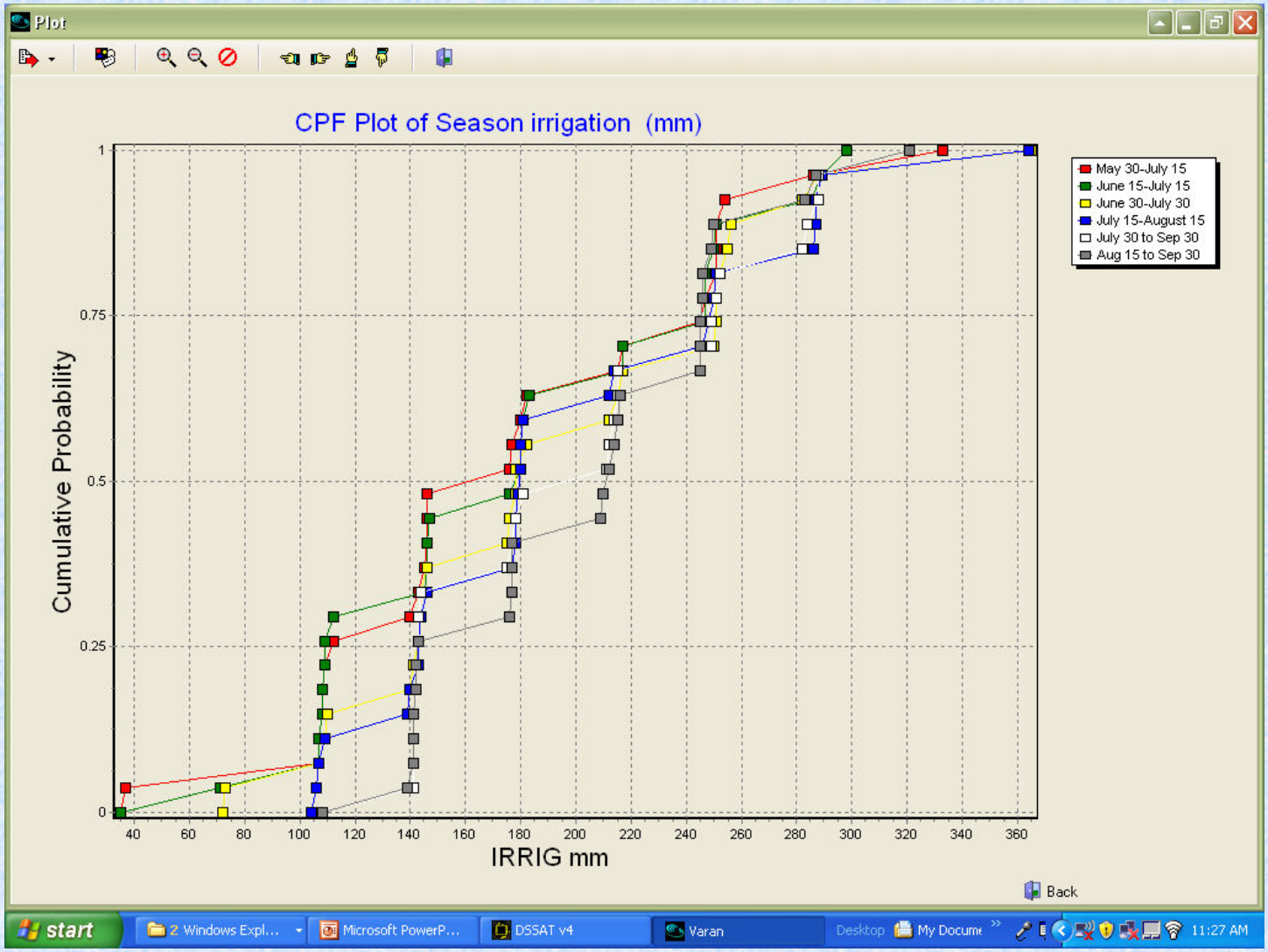
Early sowing windows allowed greater soybean yield because of longer life cycle (longer daylength) and higher ET. This graph is output of DSSAT Seasonal.



Early sowing windows allowed greater soybean yield because of longer life cycle and higher ET. Causes of higher ET: Longer cycle, better rainfall.



Irrigation requirement varied across years from 40 to 360 mm. On average, 173 to 204 mm as 5 to 6 irrigations was simulated, more for later sowings.



Findings for Soybean Crop Management, based on 28 weather years at Patancheru

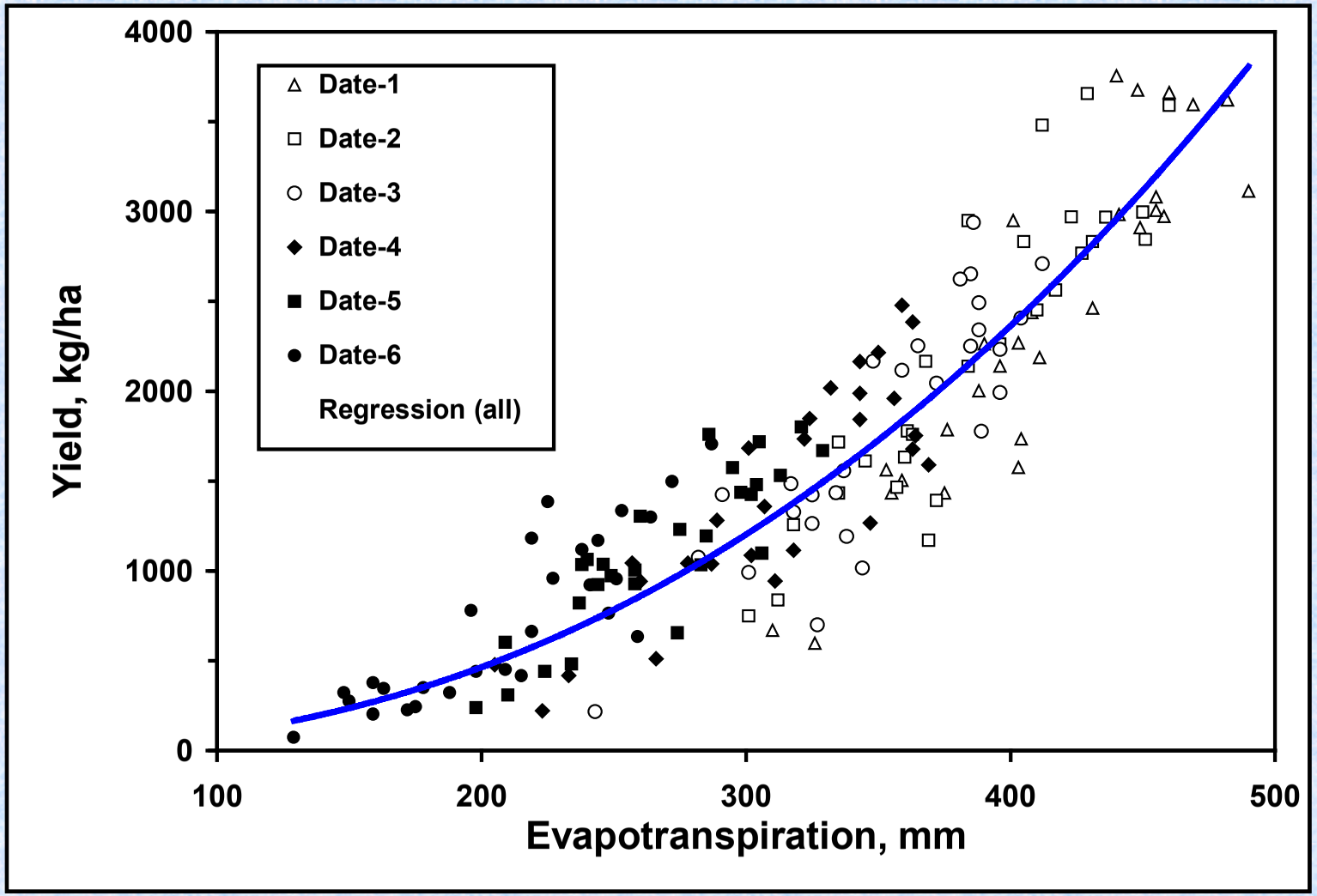
Sowing Date and Maturity Group

- Early sowing is best for yield (2380 kg/ha for MG 8) under rainfed conditions, used more of the season, higher LAI, longer cycle, and end-of-season soil water was higher.
- MG 8 was best, having high yield with lower variance than MG 9 or 10. Later MG left less end-season soil water.

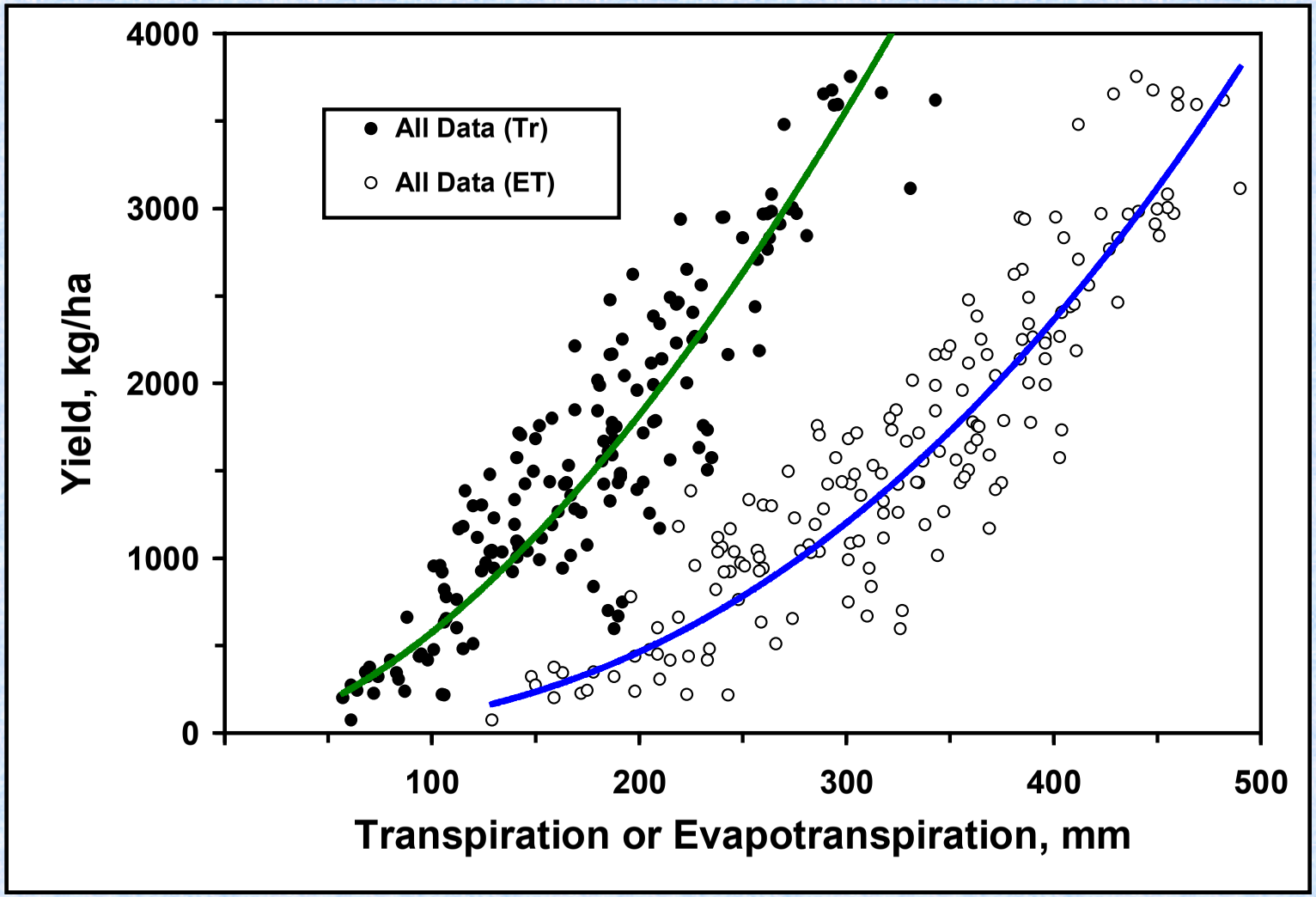
Irrigation

- ET was greater for early sowing and longer cycle MG.
- Irrigation requirement averaged 173 to 204 mm (less for early sowing), as 5 to 6 applications. Requirement ranged from 40 to 360 mm, depending on year.
- Yield was increased 1500 kg/ha with irrigation.

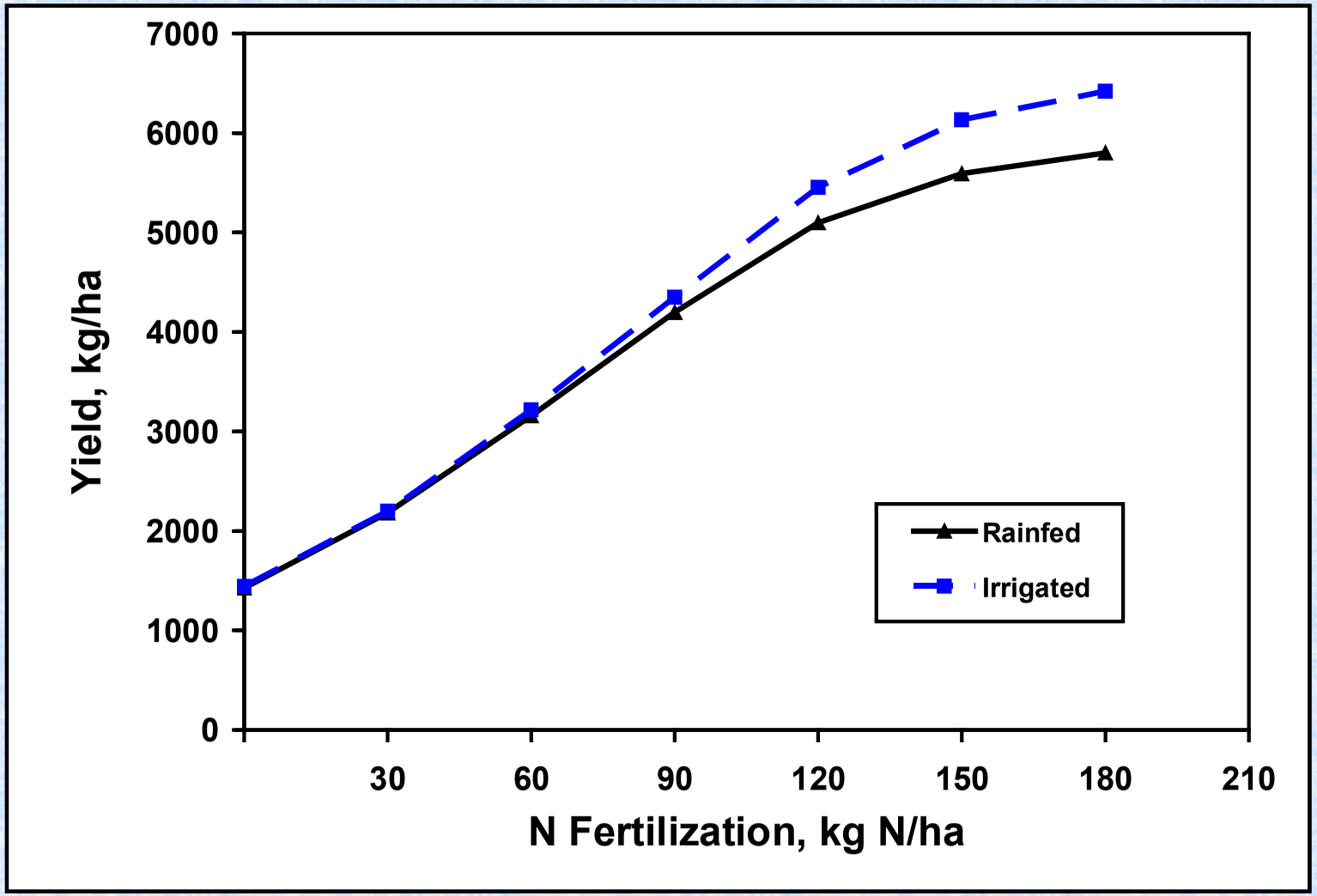
Relationship of simulated soybean yield vs. ET for six sowing dates for MG 9, under rainfed conditions over 28 weather years at Patancheru, India.



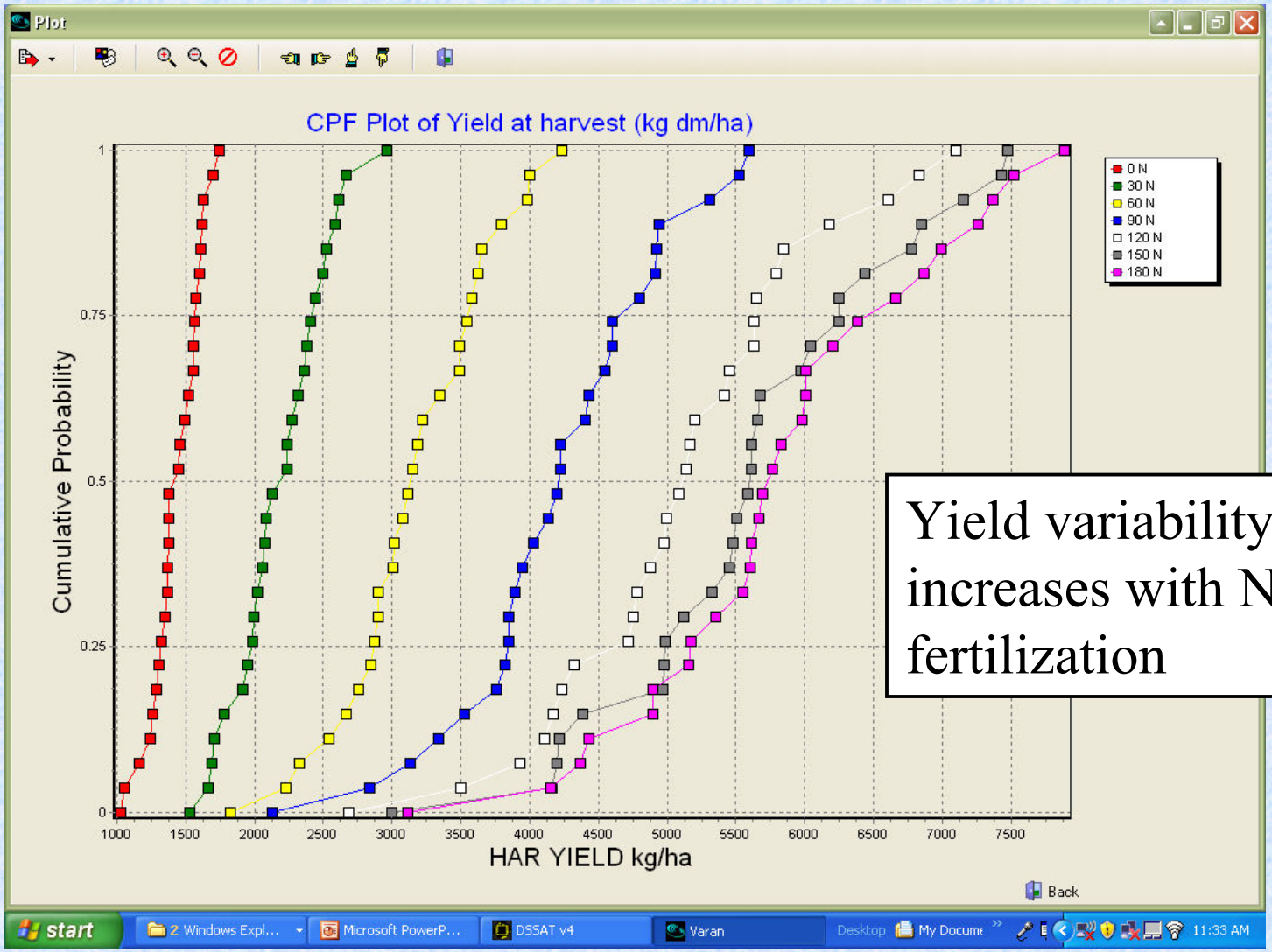
Relationship of simulated soybean yield vs. ET or transpiration over sowing dates for MG 9, under rainfed conditions over 28 weather years at Patancheru, India.



Simulated maize yield response to N fertilization under rainfed and irrigated conditions, for early sowing, averaged over 28 years at Patancheru, India

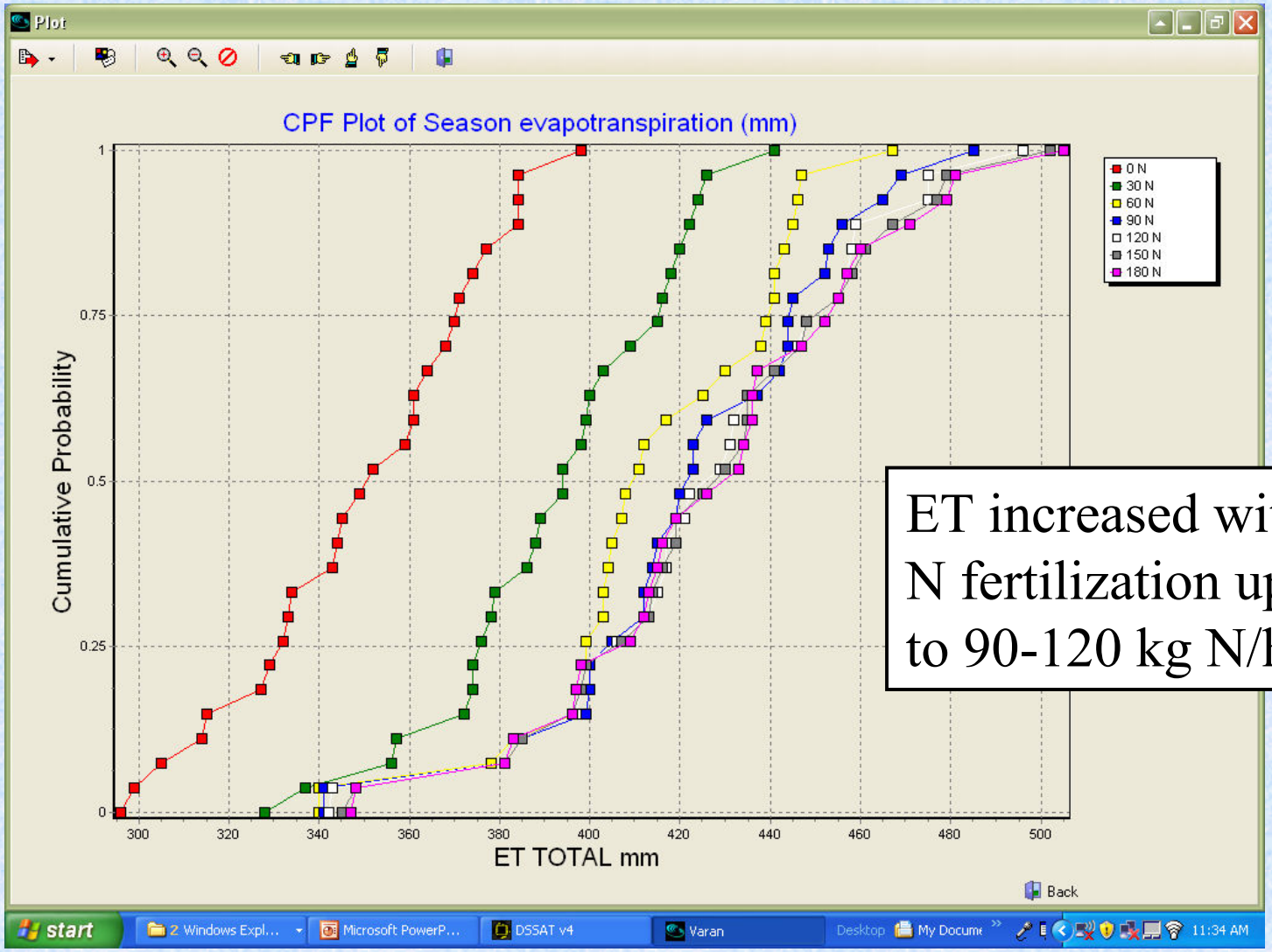


Weather-induced variability of maize yield at six N fertilization levels under rainfed conditions, for early sowing window, 28 years at Patancheru, India.



Yield variability increases with N fertilization

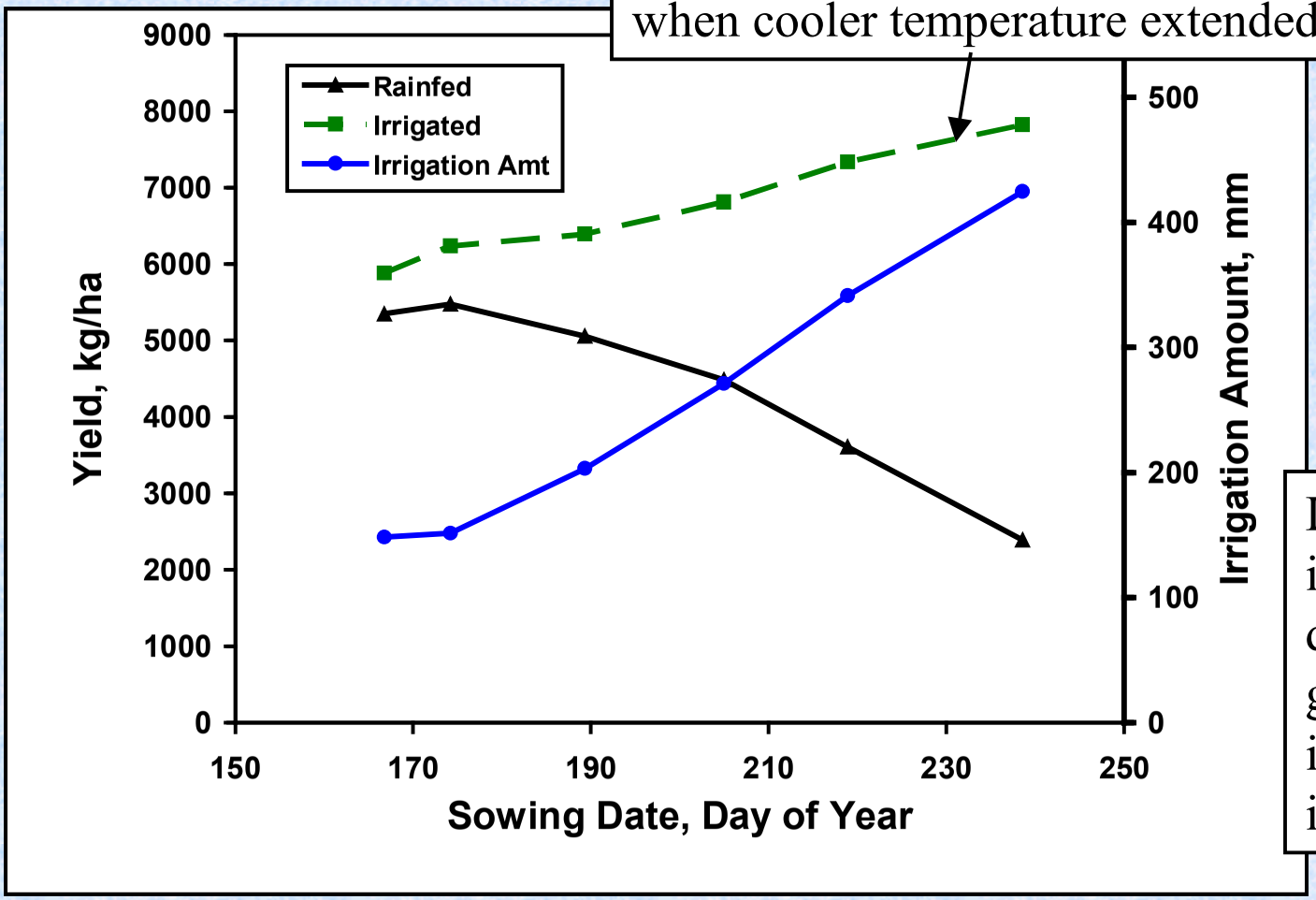
Increasing N fertilization of maize under rainfed conditions, increased LAI, soil water extraction, and ET. Distributions from 28 years at Patancheru.



ET increased with N fertilization up to 90-120 kg N/ha

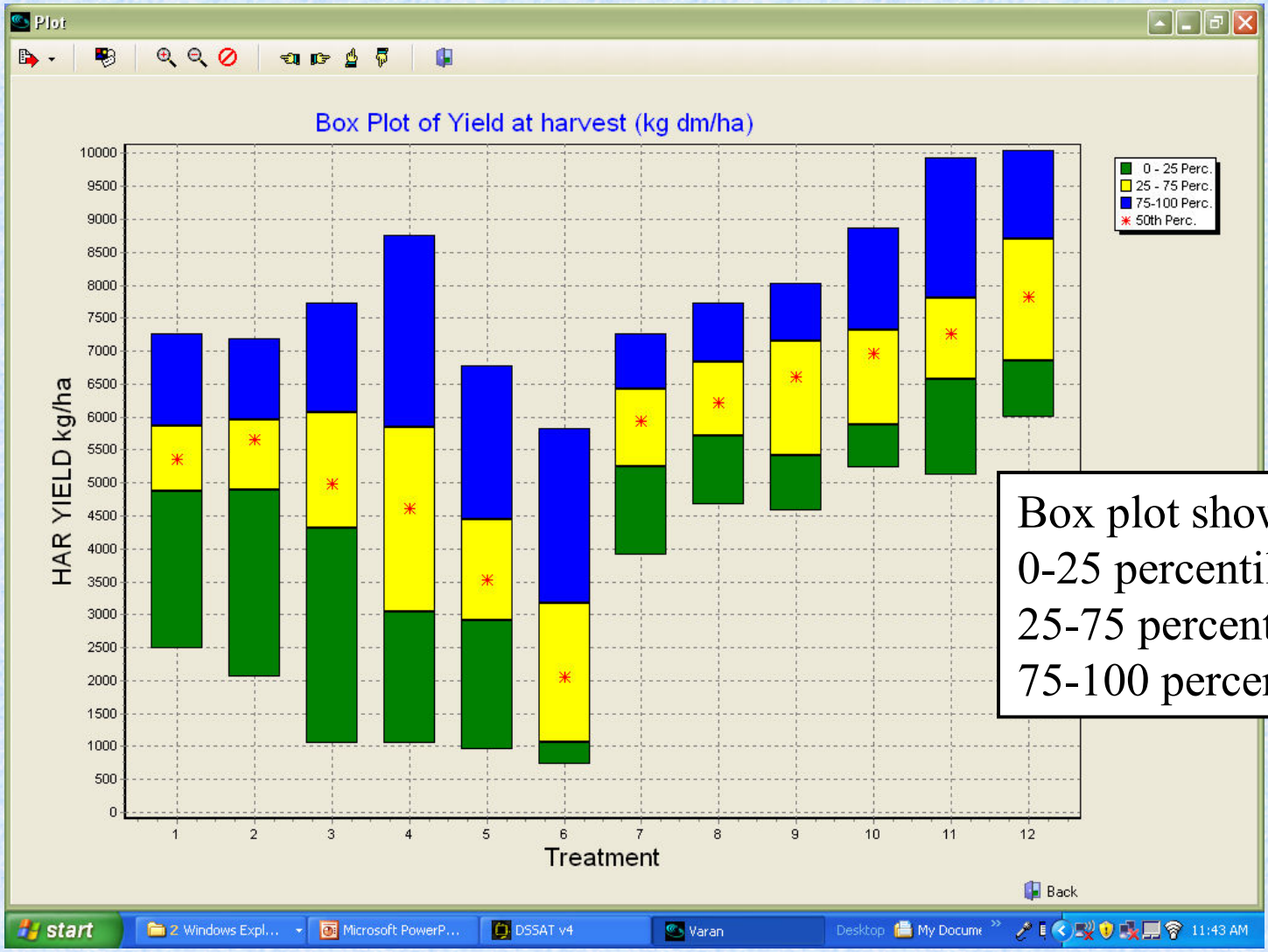
Simulated maize yield response to sowing date under rainfed and irrigated conditions, with 120 kg N/ha, averaged over 28 years at Patancheru, India.

Irrigation increased yield more for late sowing, when cooler temperature extended grain filling



Later sowing increased water deficit during grain-filling, increasing irrigation req.

Box plot of simulated maize yield response to sowing date under rainfed and irrigated conditions, with 120 kg N/ha, over 28 years at Patancheru, India.



Box plot shows:
0-25 percentile,
25-75 percentile,
75-100 percentile.

Findings for Maize Crop Management, based on 28 weather years at Patancheru

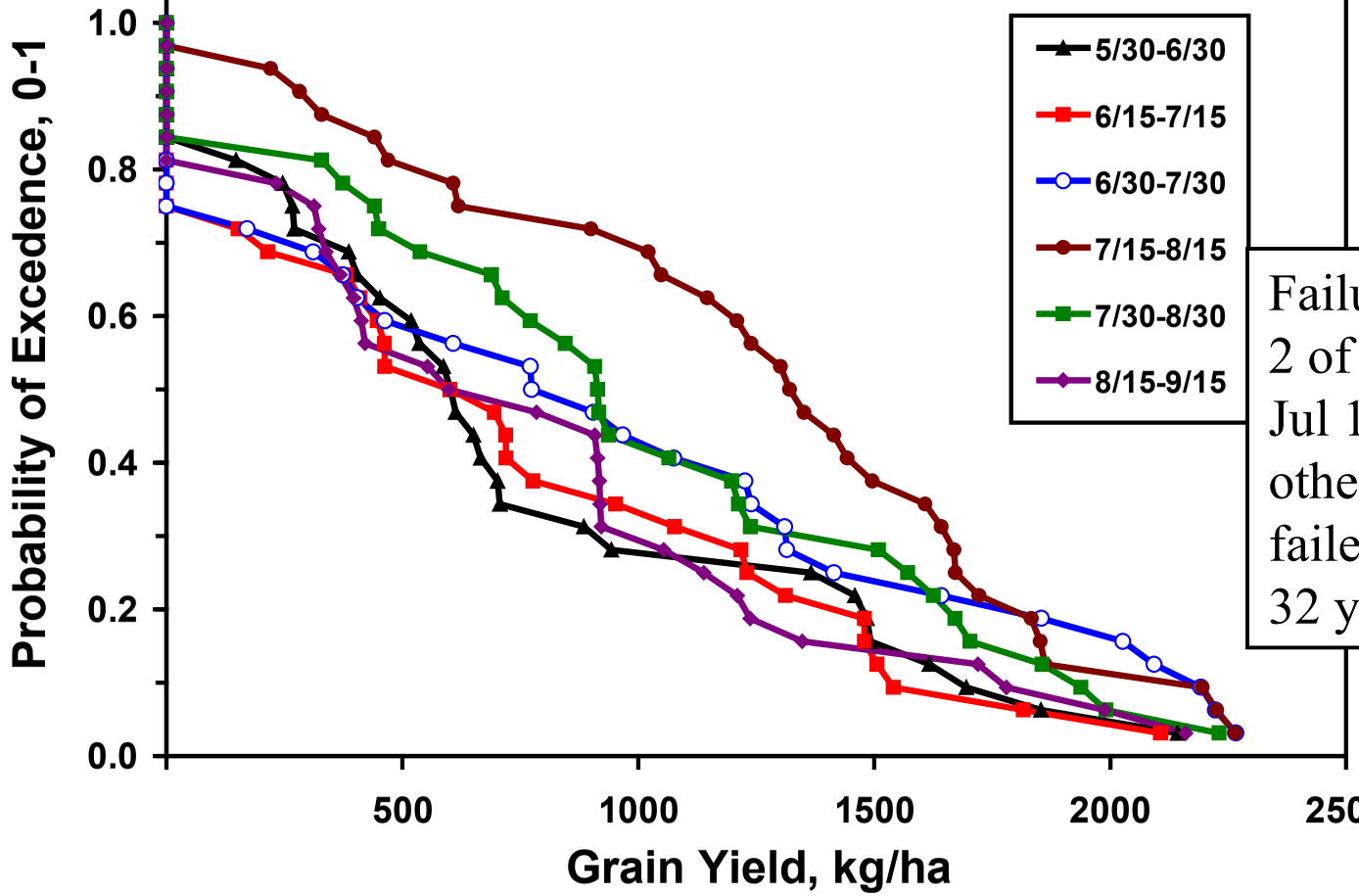
Sowing Date and N Fertilization

- Early sowing is clearly best for yield under rainfed conditions, fit rainfall pattern better, and end-of-season soil water was higher. Late sowing caused water deficit.
- N fertilization up to 150 kg N/ha increased yield to 5800 kg/ha, increasing LAI, ET, and soil water extraction under rainfed conditions. Irrigation increased response to N.

Irrigation

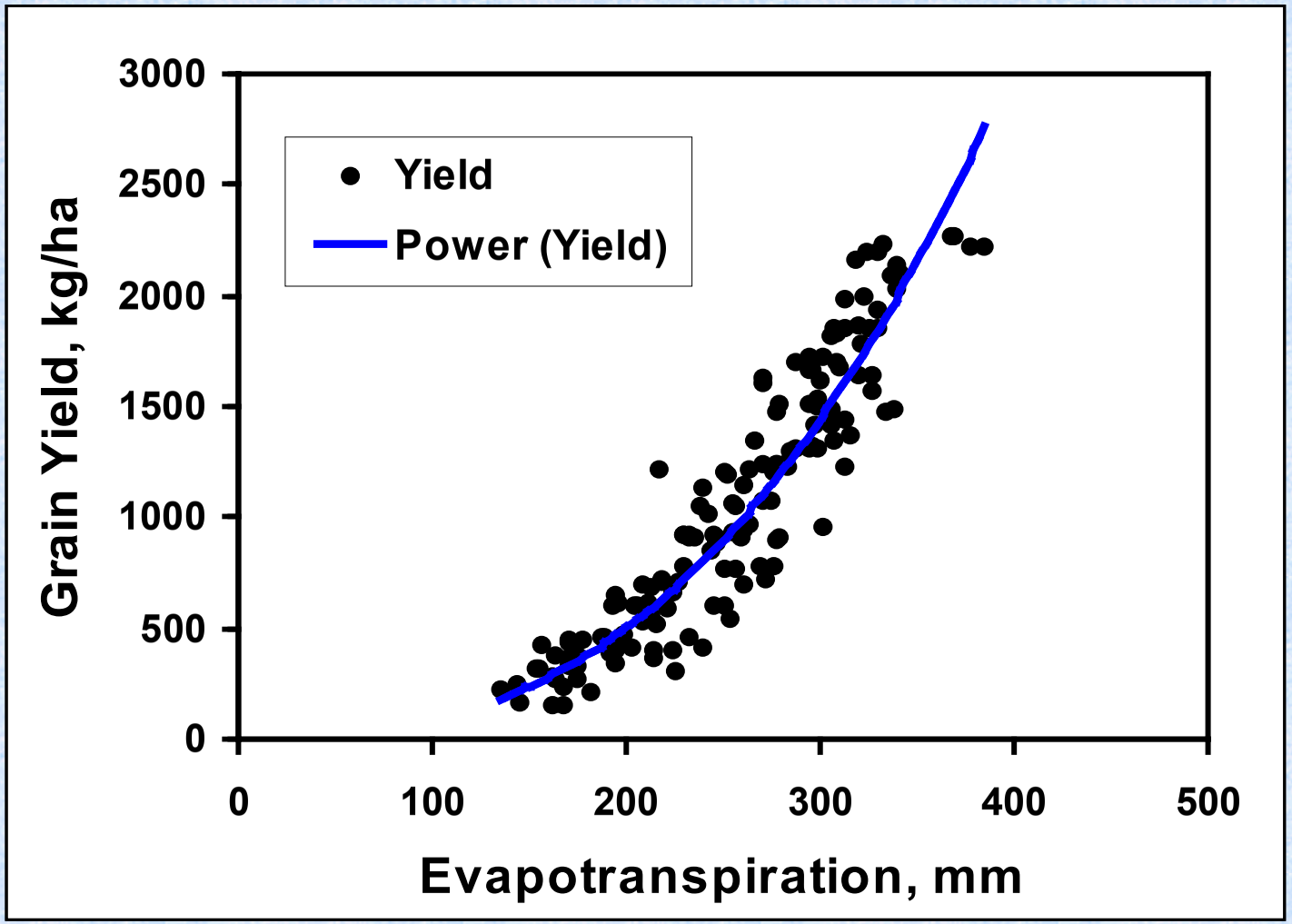
- ET was greater for early sowing under rainfed conditions.
- Irrigation requirement increasing progressively from early to late sowing, from 148 to 425 mm (on average).
- Irrigation increased yield very little for early sowing, but progressively increased yield for later sowing dates.

Probability of attaining a given grain yield for Robut 33-1 peanut vs sowing date, under rainfed conditions at Anantapur, India (32 years). July 15 to Aug 15 was clearly superior sowing window.

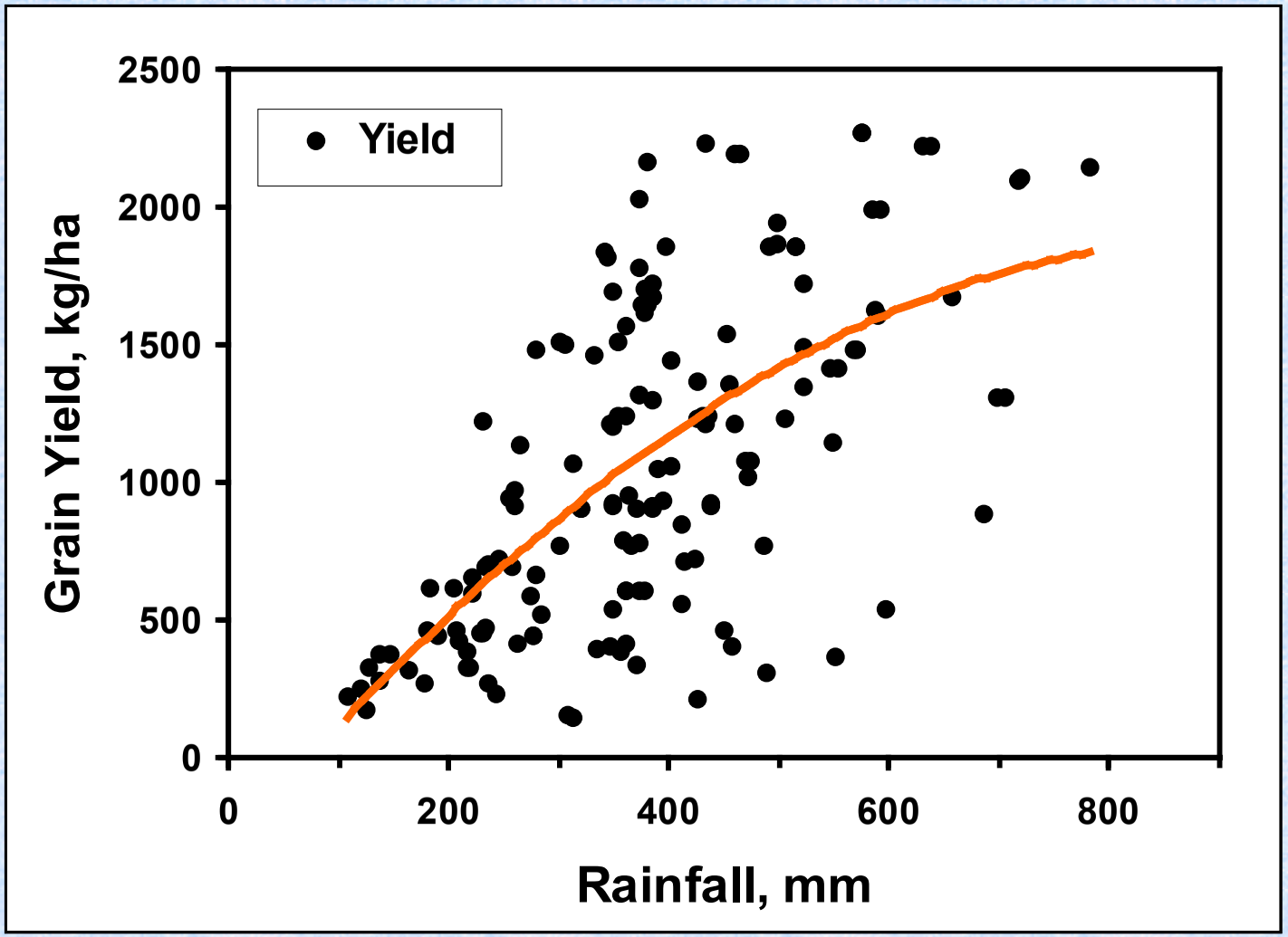


Failure to sow 2 of 32 yr for Jul 15-Aug 15; other windows failed in 6+ of 32 yrs.

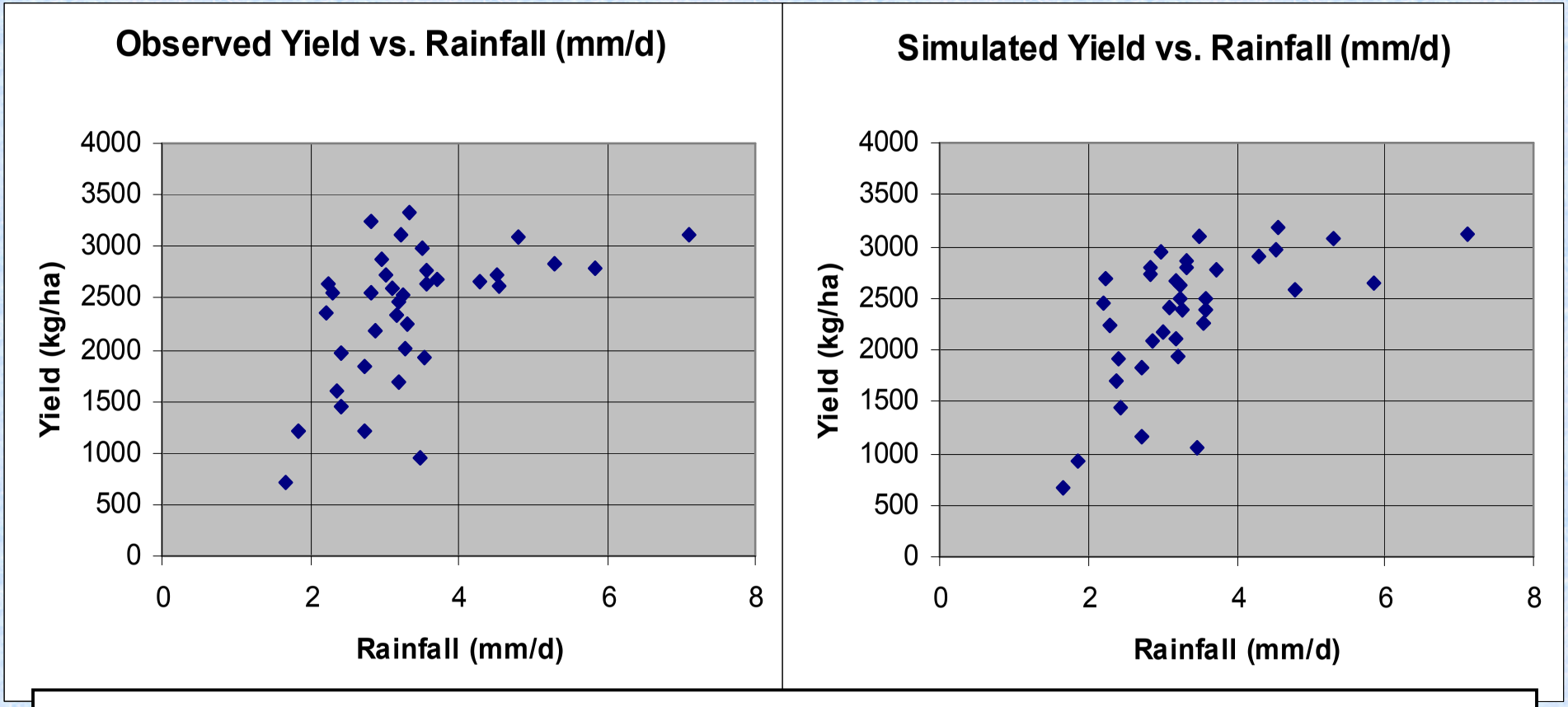
Relationship of simulated grain yield vs. ET over six sowing dates for Robut 33-1 peanut, under rainfed conditions over 32 weather years at Anantapur, India.



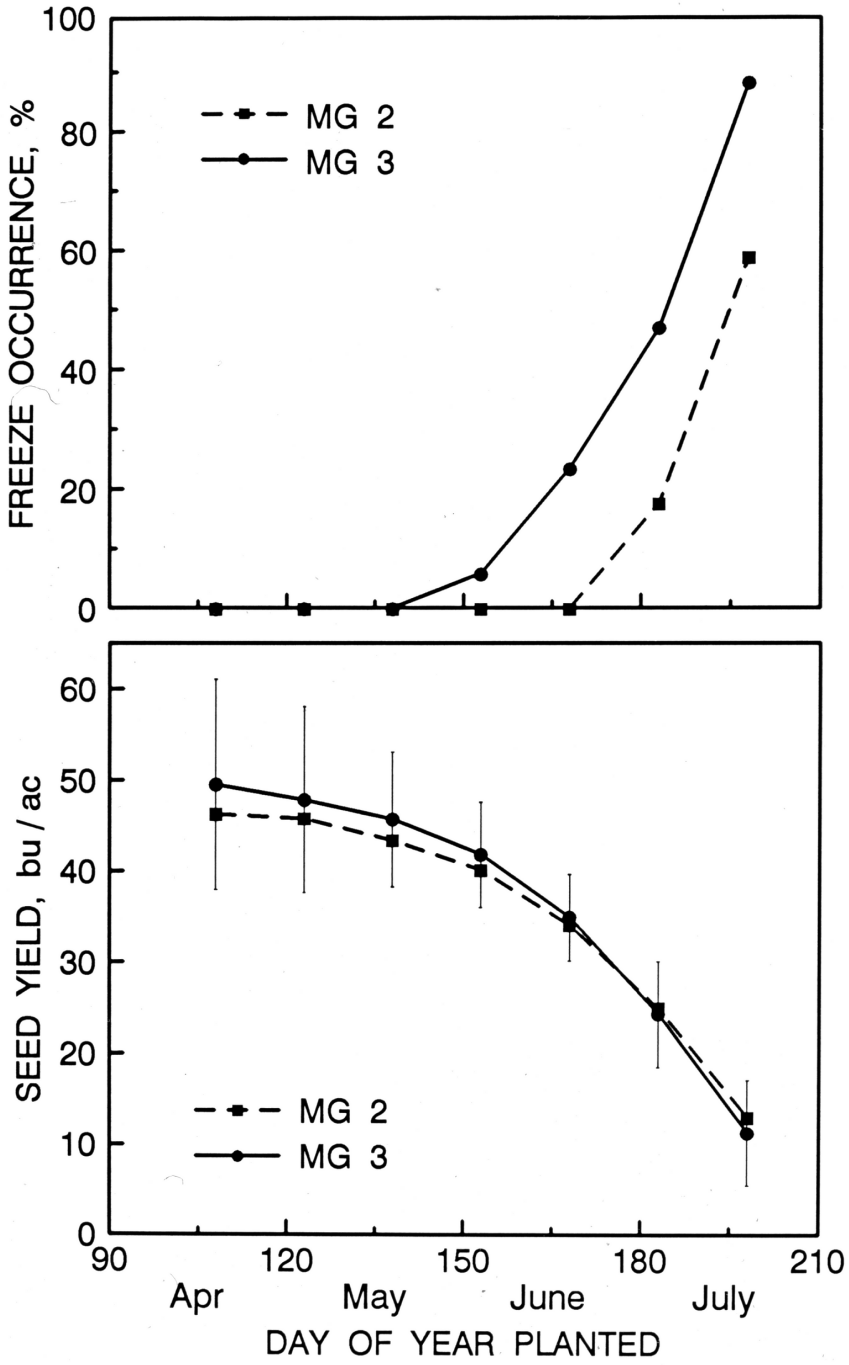
Relationship of simulated grain yield vs. rainfall over six sowing dates for Robut 33-1 peanut, under rainfed conditions over 32 weather years at Anantapur, India.



Relationship between seasonal rainfall and soybean yield; Observed (Georgia yield trials) and Simulated



Why not "clean" relationships? You may have high seasonal rainfall but poor rainfall distribution causes water deficit and low yield!

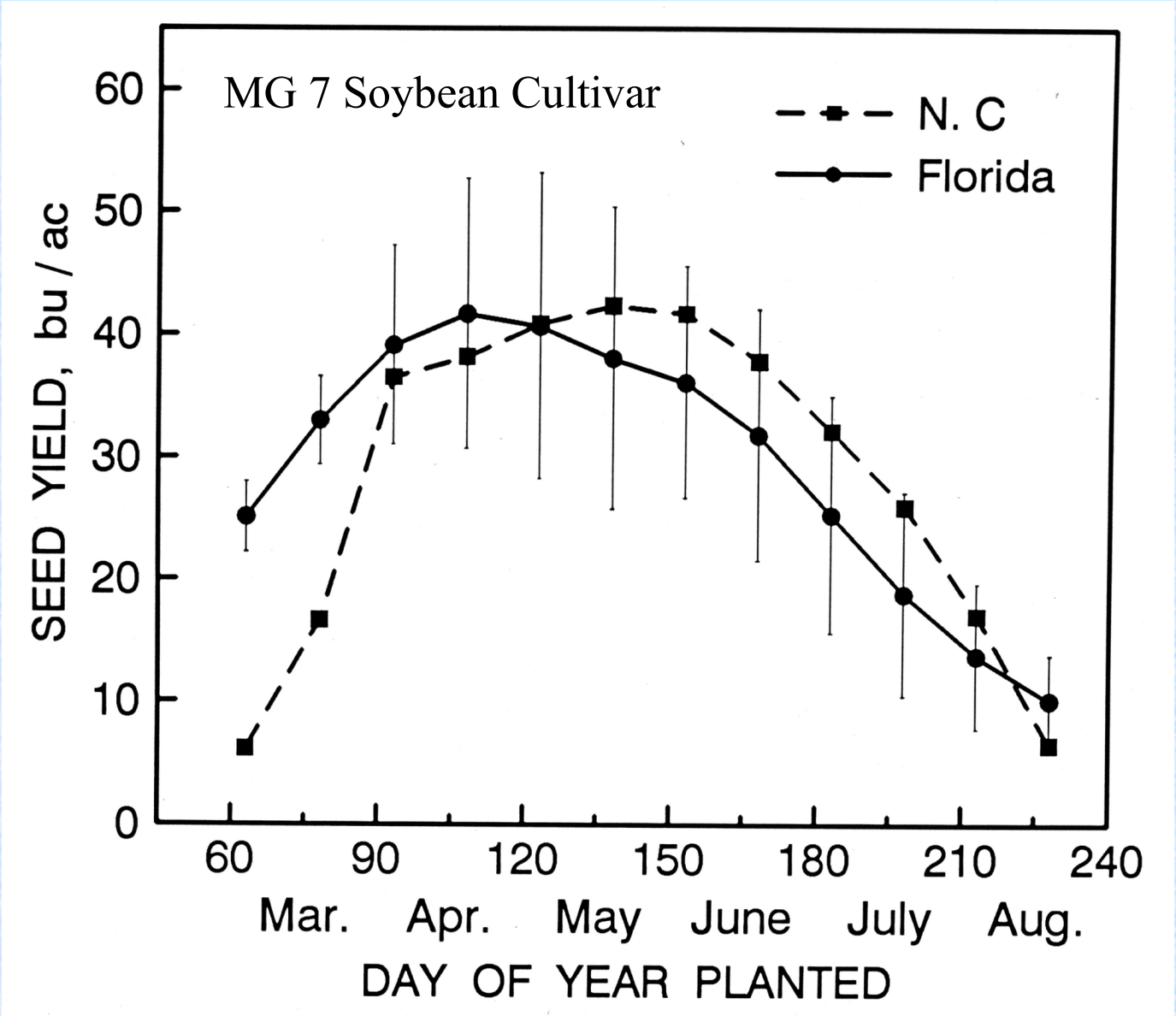


Example of Daylength & Temperature Effects: Optimizing Crop Management to Increase Yield and Reduce Weather Risk.

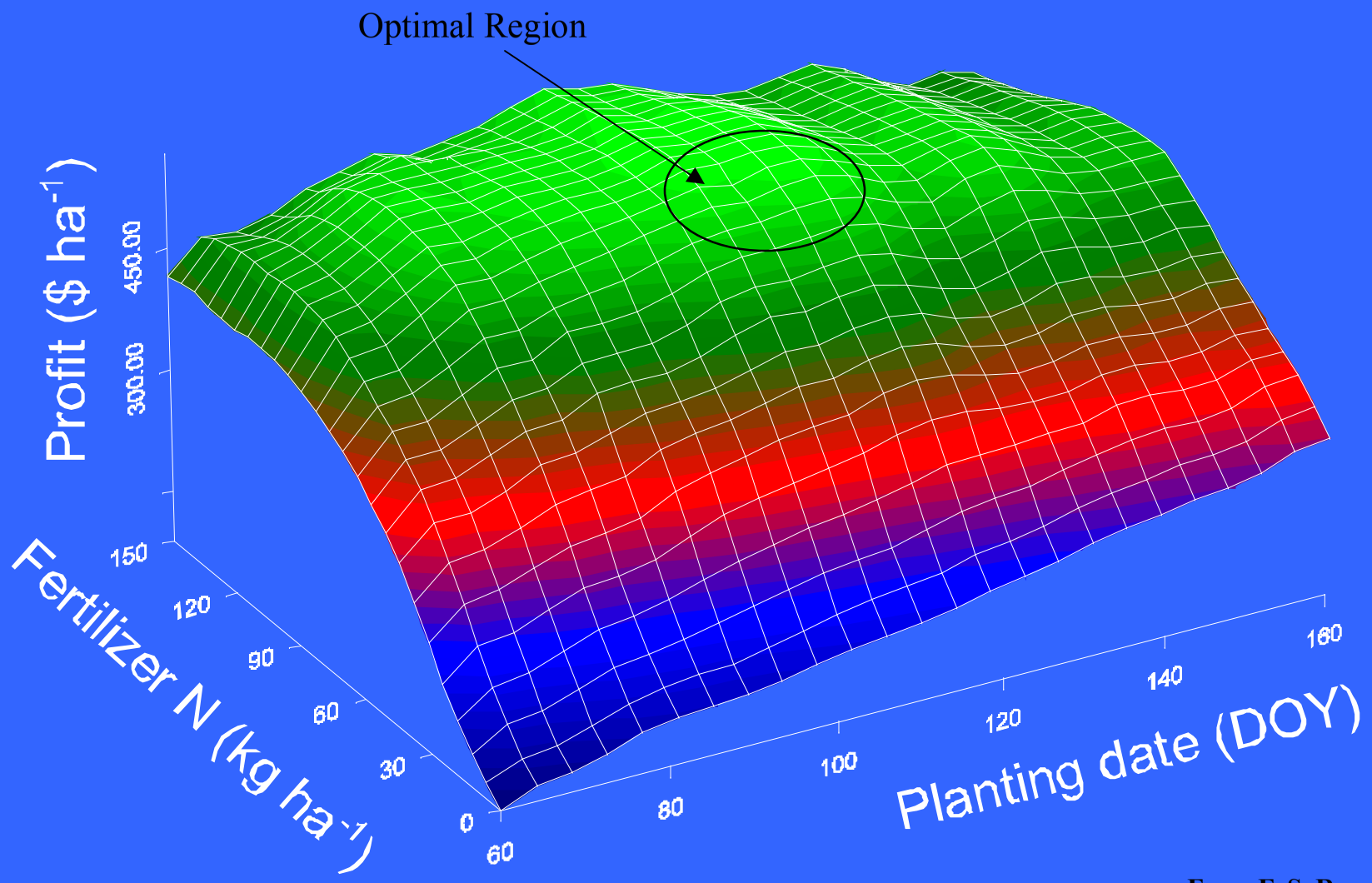
Yield and risk of freeze damage for two soybean MG vs. sowing date in Iowa.

Impact of sowing date, cultivar, & seasons:

Yield vs. sowing date, in Florida and North Carolina. Error bars show seasonal range over multiple years.



Climate Prediction Application: *El Niño*
Maize, Camilla, GA (USA) 1951-95



From F. S. Royce, UF

Crop Models as In-Season Agro-Advisory Tools:

In-Season Decisions

- Run model with real weather up to today, then short-term forecast, then ENSO forecast or historical. Ask question.
- Run model, with or without altered management. Profit?

Irrigation and N Fertilization

- Run model, predict date of water deficit, recommend irrigation. Decision: profit with or without irrigation.
- Run model, predict yield with or without N applied today. Advantage: accounts for recent leaching rains.

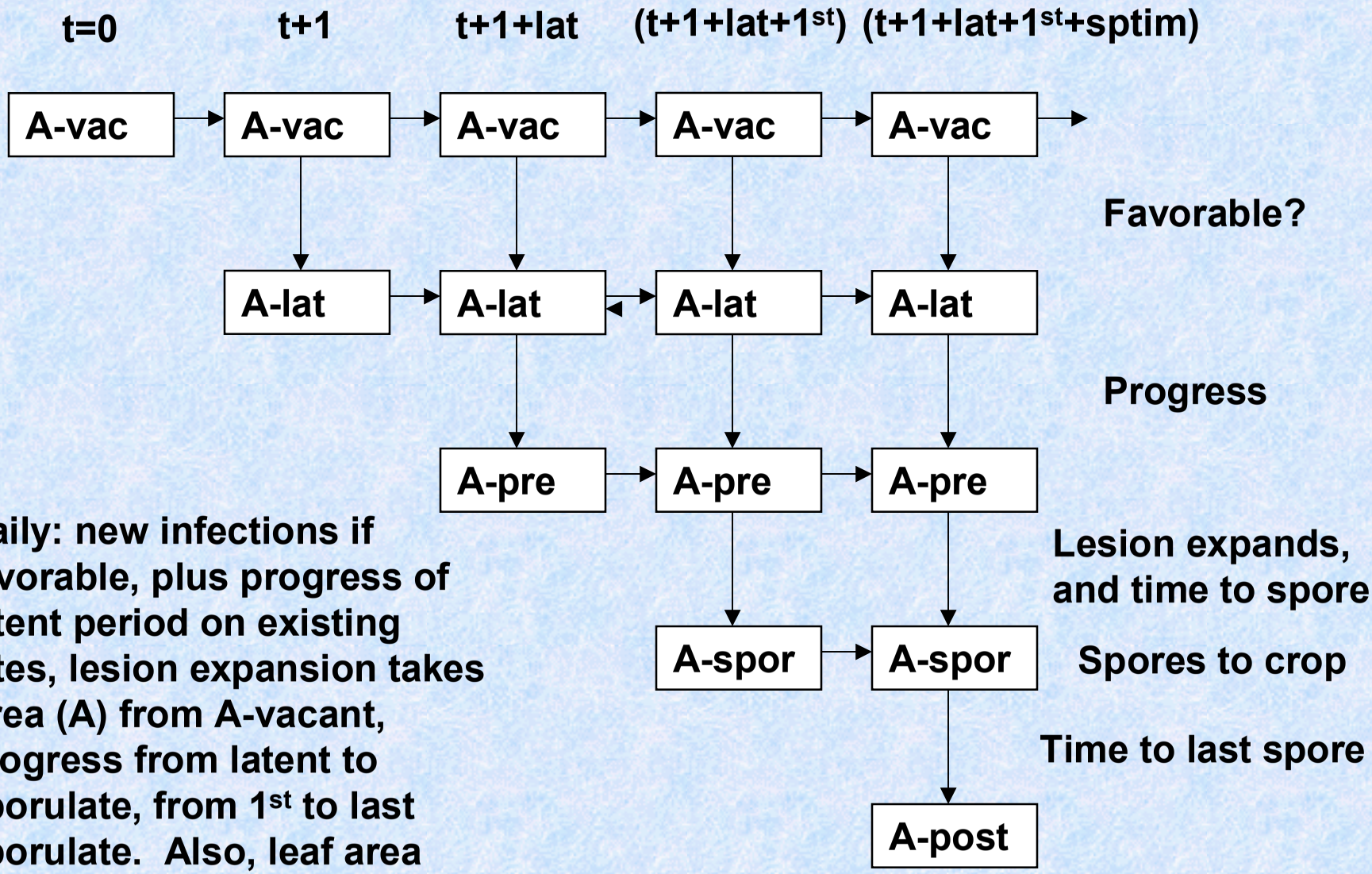
Leafspot Spray/Aflatoxin

- Run model, predict yield response to leafspot disease, apply fungicide based on profit, also temp/RH forecast
- Run model, predict aflatoxin increase, with or without irrigation. Recommend irrigation to stay below thresh.

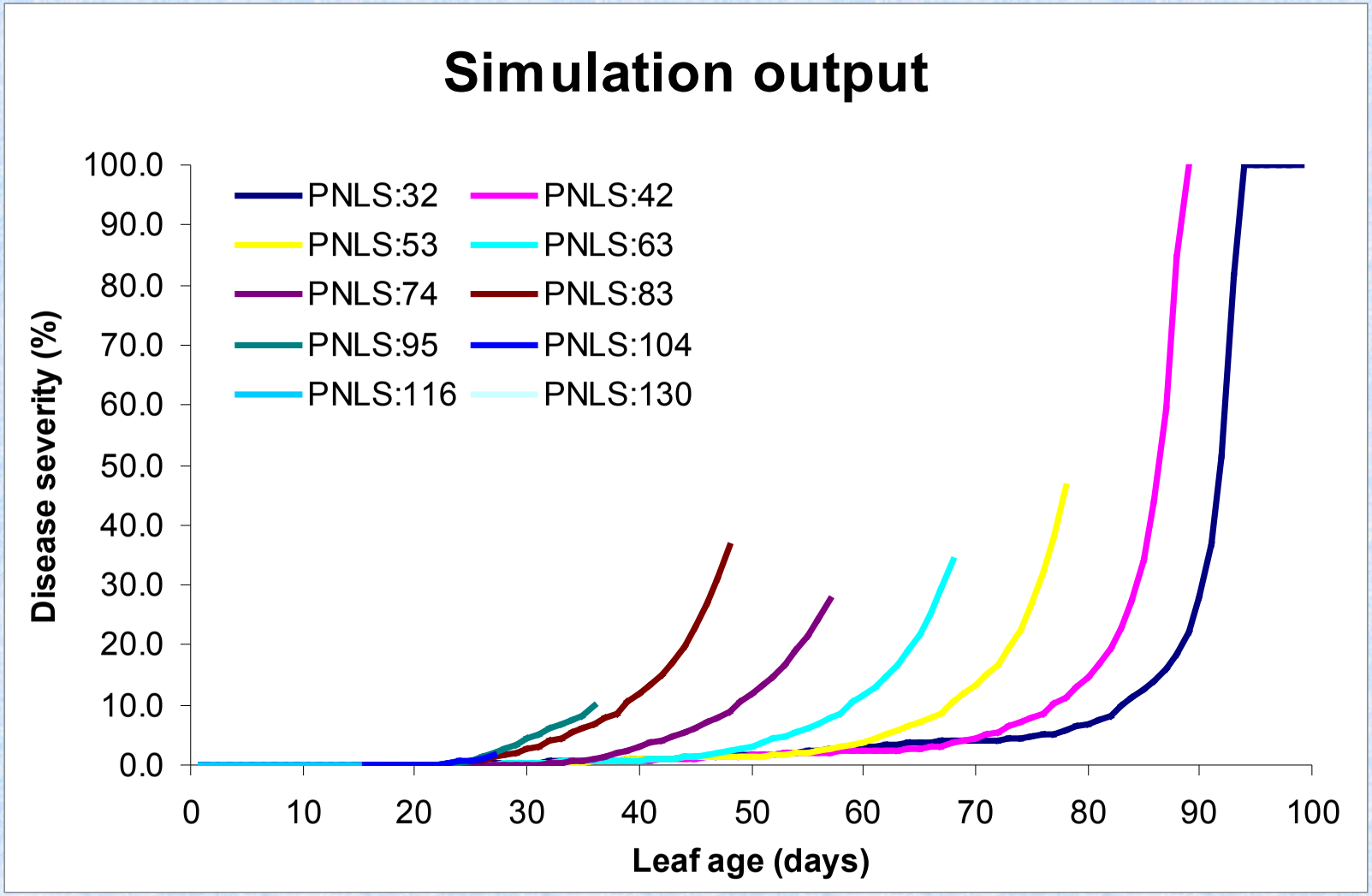
Testing CROPGRO-Peanut and Applying it for Weather Risk and Disease Risk

- CROPGRO-Peanut: Well tested for response to weather and soil water balance with 45 treatments in USA, 8 in Australia, >30 in India, 98 in Ghana, and 100+ in Thailand. On-farm tests in USA (24) and Ghana (60).
- LATE SPOT disease simulator of Bourgeois linked to PNUTGRO model (will link to V4.0 of model):
  - Code predicts infection, latent period, lesion expansion, and sporulation (polycyclic epidemic) on leaf cohorts.
  - Depends on temperature, rel. humidity, computed dew duration
  - Affects leaf photosynthesis and leaf abscision.
- Current V4.0 predicts *aspergillus* infection & aflatoxin synthesis in seeds (% infection, ppb aflatoxin)
  - Depends on pod zone environment (soil temperature, soil water, and plant turgor), relative to pod cohorts as they are produced.

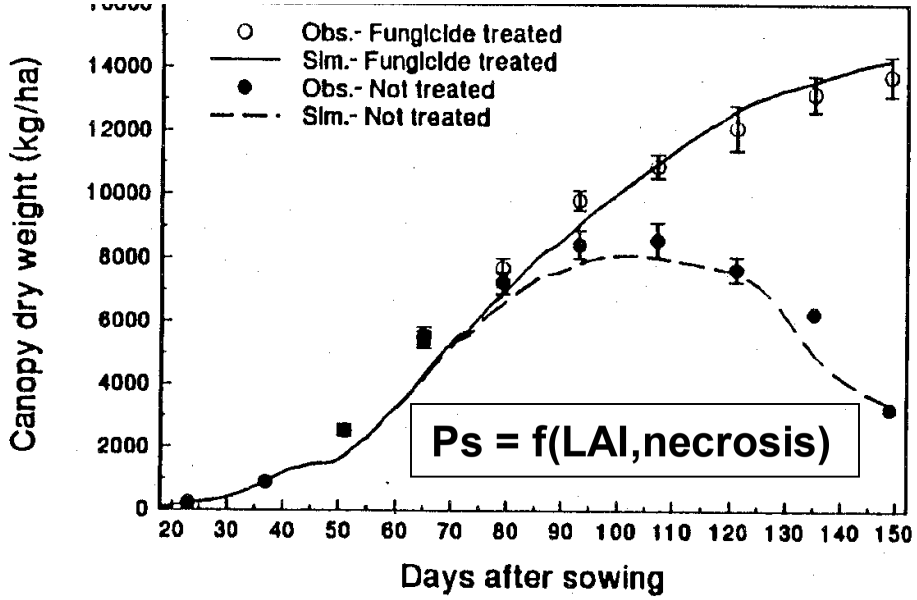
Leaf spot Disease on a Single Leaf Cohort

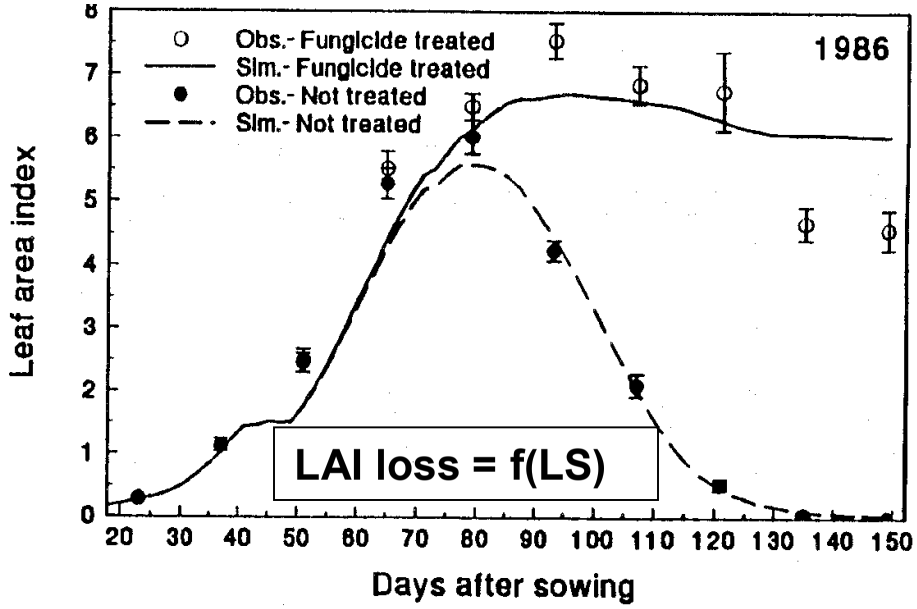


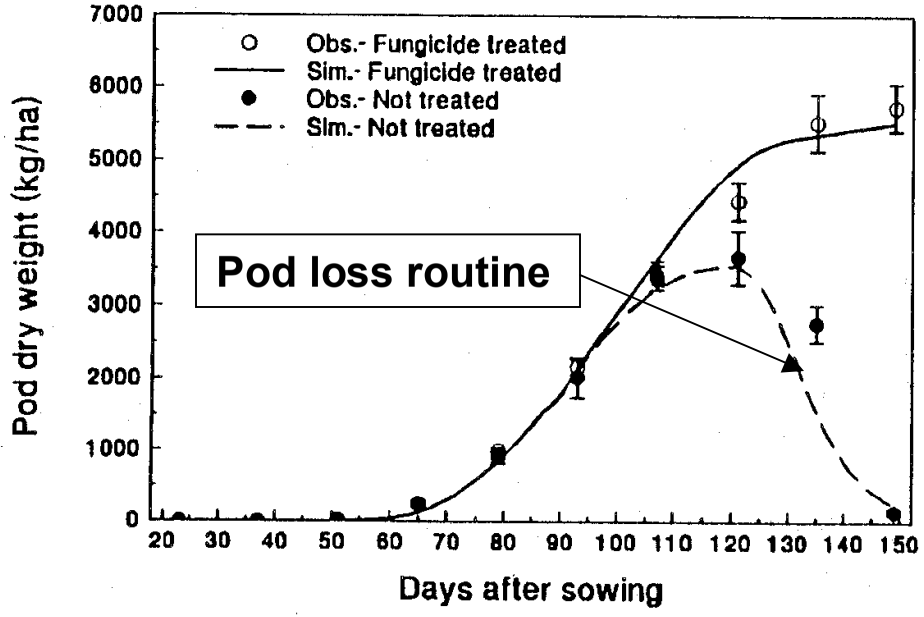
Example: Disease progression on individual leaf cohorts. Total Disease Severity = necrosis plus abscission of the leaves average for whole cohort for unsprayed Florunner.

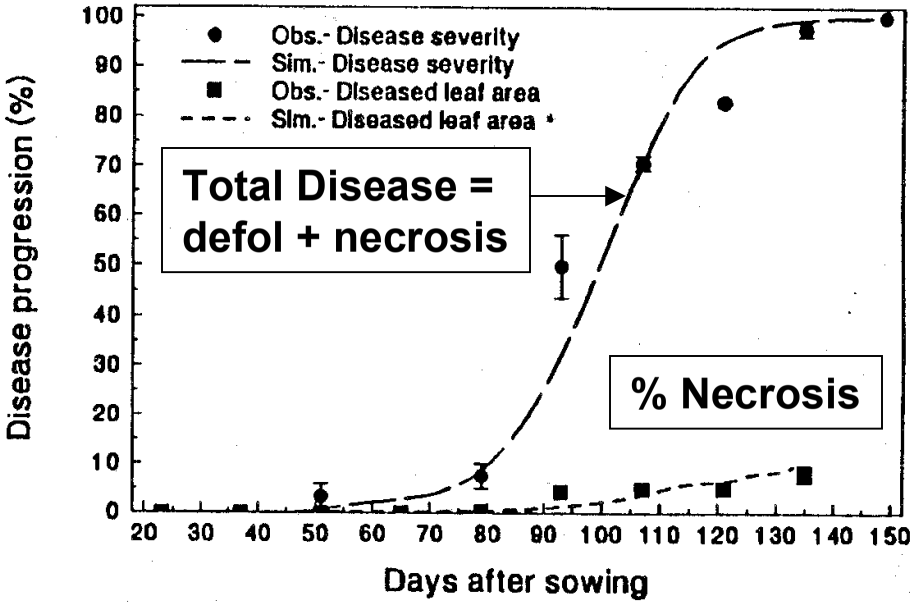


Simulated growth/disease w PNUTGRO-LATESPOT model (Bourgeois)

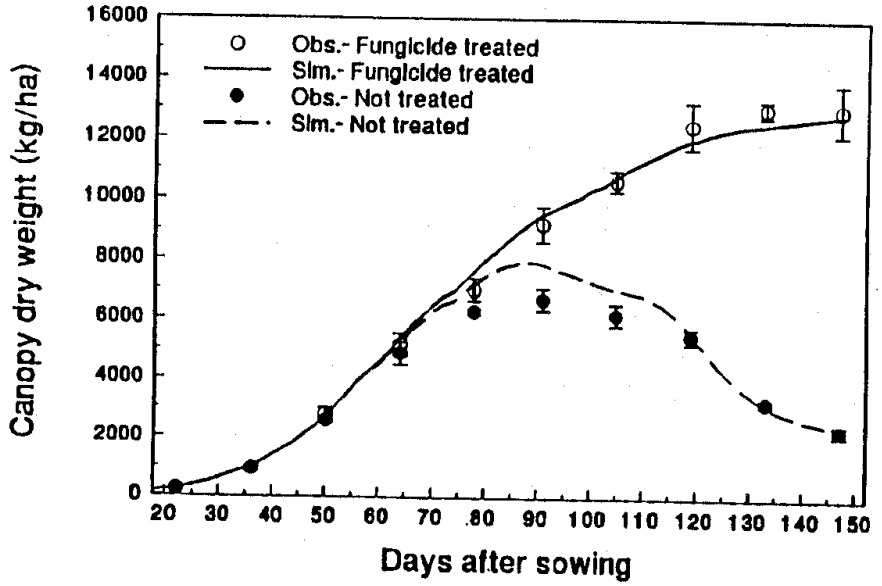


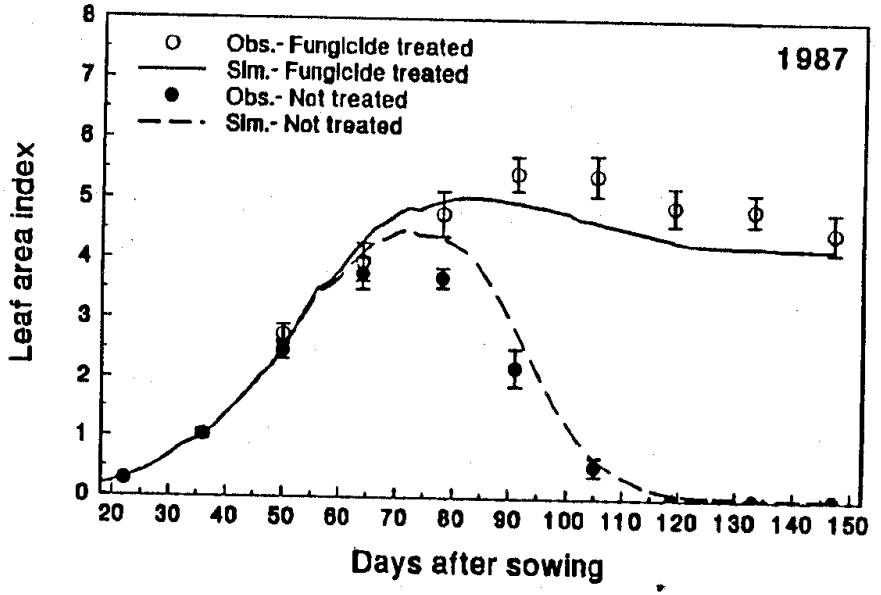


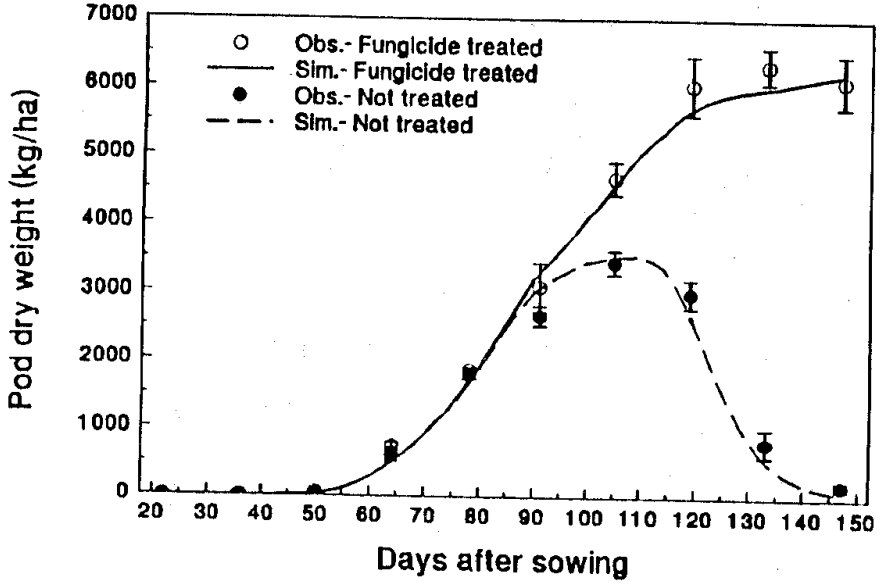


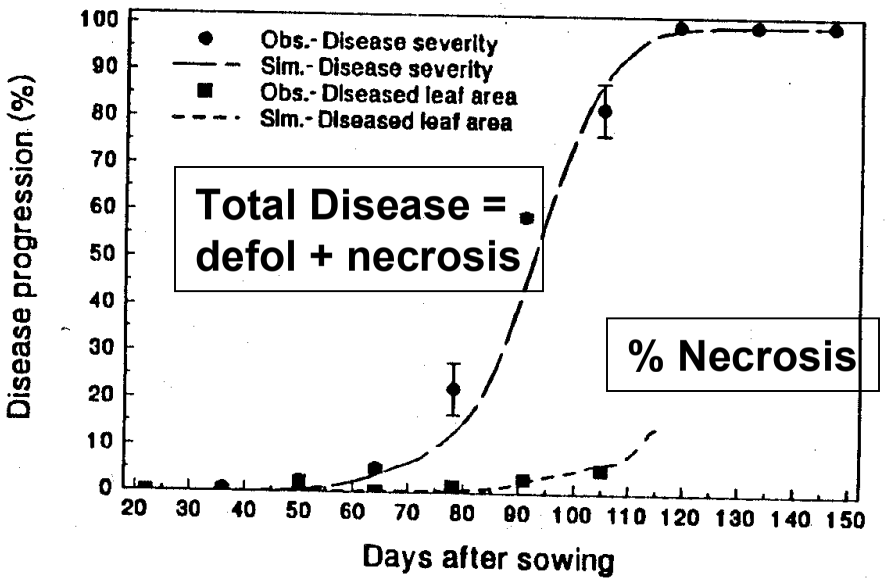


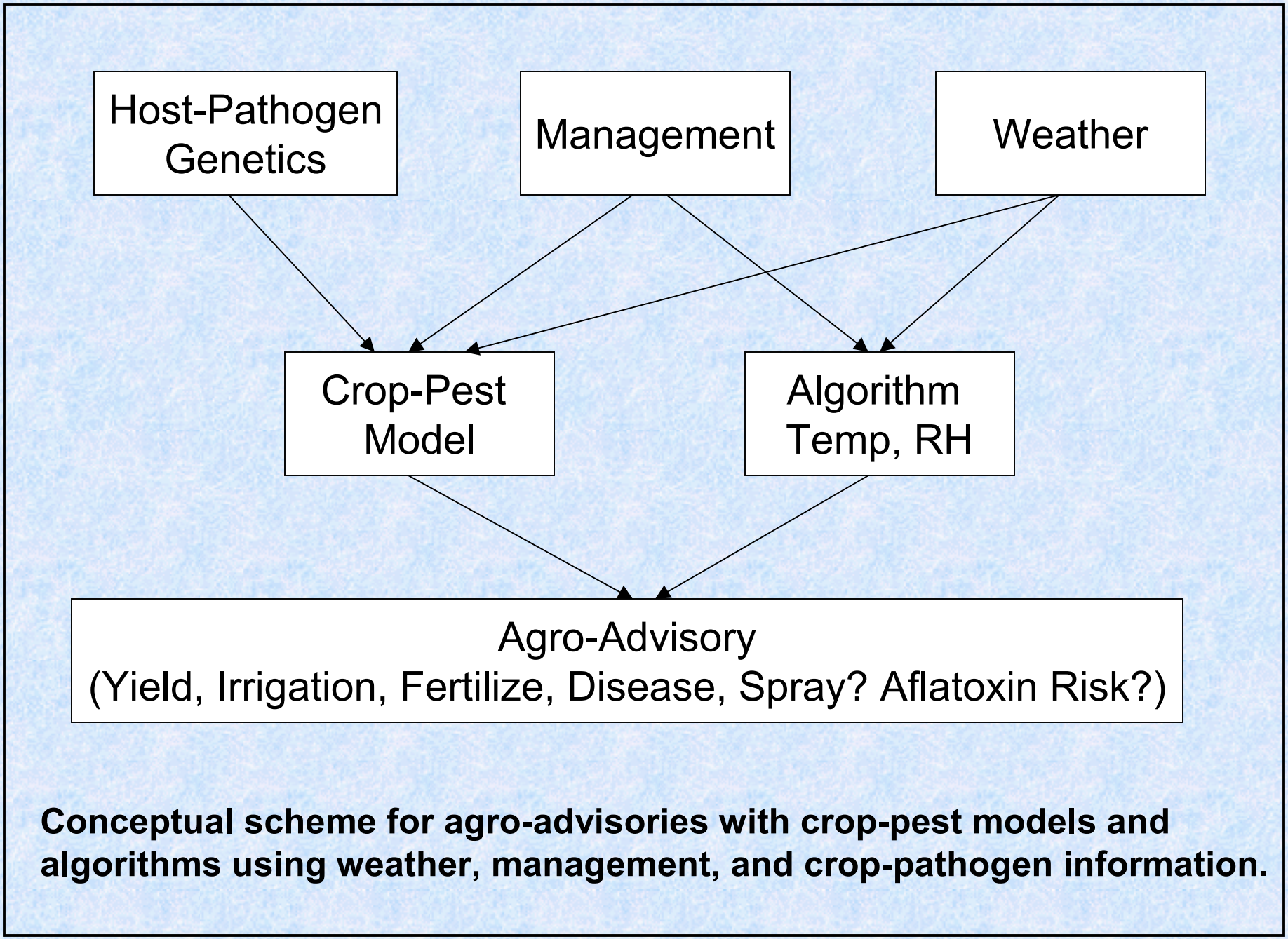
Simulated growth/disease w PNUTGRO-LATESPOT model (Bourgeois)











Conceptual scheme for agro-advisories with crop-pest models and algorithms using weather, management, and crop-pathogen information.

Conclusions

- **Crop models have good unrealized potential as agro-advisory tools for DSS.**
- **Strategic (pre-plant) based on long-term weather: sowing date, cultivar type, N fertilization plan, & irrigation strategy.**
- **In-season based on current weather: N fertilization, irrigation, fungicide spray, aflatoxin prevention. All unrealized yet!!**