THE PLANTING DATE CALCULATOR: A DECISION-SUPPORT TOOL FOR AGRICULTURE

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ABSTRACT

The Planting Date Calculator is an agricultural decision-support tool developed by the University of Nebraska – Lincoln, Computer Science and Engineering Department. The software assists farmers and crop consultants with the important decisions of selecting a hybrid and scheduling planting. It allows the user to interactively 1) locate and delineate a field; 2) schedule planting and project the growing season based on historical climate data, risk tolerance, and other factors; and 3) examine and compare hybrids appropriate for the location, planting schedule, and growing season. The tool is available as an application service from the University of Nebraska via a Java applet over the World-Wide Web (WWW) at www.plantguide.com.

INTRODUCTION

The Nebraska Research Initiative on Geospatial Decision Support Systems is developing a set of agronomic decision-support tools that produce economic value in agriculture by integrating the wealth of geospatial data and information available in Nebraska. The decisions of selecting a hybrid and scheduling planting are among the most important in agriculture (Nelson, 1991). For example, farmers invest $30 to $50 per acre for corn hybrid seed, and selecting and planting a hybrid better suited for the growing season and available heat units may increase productivity 5 to 10 bushels per acre (Roth, 1992; Hicks *et al.*, 1992). The potential economic value of improved decisions is large because corn is grown on 20% of crop acres in the United States and over nine million acres in Nebraska alone (USDA, 2000).

An important goal in selecting a hybrid and scheduling planting is to maximize yield and a principal constraint is the availability of heat during the frost-free growing season. Crucial elements in the decisions include the risk of spring and fall freezes, timely access to the field, the length of the growing season, the expected available heat units, and short and long term weather forecasts (Neild, 1983; Neild, 1986; Nelson, 1991). These factors vary greatly with geographic location and terrain (Roth, 1991). In considering the uncertainties in these elements, the decision process must accommodate the risk tolerance of the decision-maker.

The Planting Date Calculator is a decision-support tool for selecting a hybrid and scheduling planting. The system allows consideration of various factors including geography, climate history, risk tolerance, and available hybrids. The software has three principal components, each of which is detailed in following sections.

- The **Field Finder** tool allows the user to interactively locate and delineate a field by drilling down from a low-resolution, statewide image to a high-resolution, aerial photograph.
- The **Growing Season** tool allows the user to interactively plan the schedule for planting and maturity with interactive feedback of important historical climate data and risk factors.

- The **Hybrid Selector** tool allows the user to view and compare attributes of various hybrids appropriate to the growing season.

The software is available over the World-Wide Web (WWW) at www.plantguide.com. The **Technical Details** section describes the implementation as an application service with Java applets that run on the user's computer and Common Gateway Interface (CGI) programs that run on the server computer. The **Conclusion** section describes directions for future research and development.

FIELD FINDER

The Field Finder tool allows the user to locate and delineate a field. This geographic information is important in later steps of the Planting Date Calculator, for example, in retrieving historical climate data for the field location. Geographic information also provides unique identification of specific fields for the archive of data about the field, for example crop rotations and other cropping practices. Archive data about specific fields will be used in future Plant Guide software to make more comprehensive analyses in support of planting decisions.

The Field Finder allows users to drill down from a low-resolution, statewide image to a high-resolution, aerial photograph in three steps or levels and returns the geo-referenced location of a field. Currently, the system implements this process for anywhere in Nebraska.

The first level of the Field Finder presents a shaded relief map at 1-kilometer resolution with an overlay of county boundaries. A window-shot of this level is pictured in Figure 1. Nebraska is 687 km east-to-west and 333 km north-to-south and so fits well on a computer monitor at 1 km resolution. The graphical user interface (GUI) presents a yellow selector box for the user to locate the general area containing the field. The user moves the box over the area of the field and then clicks the mouse button to select the region.

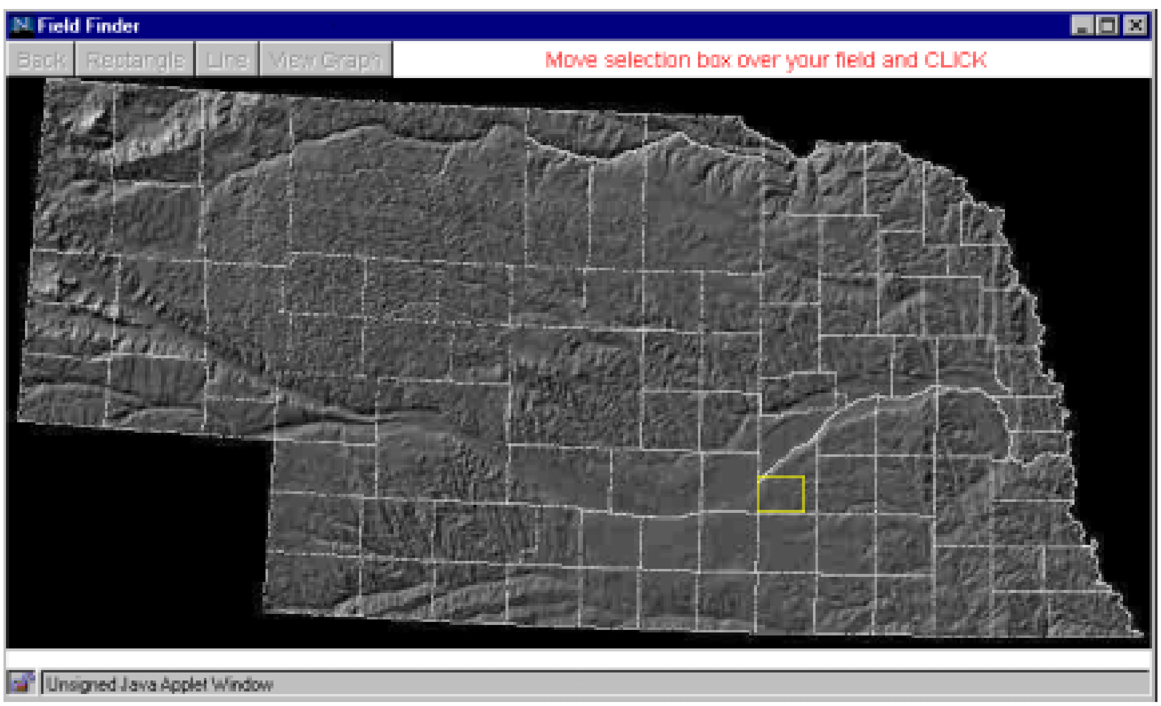

Figure 1. Field Finder Level 1 — Nebraska shaded relief image with white county outlines and yellow selector box.

The server delivers to the user the Level 2 image of the area selected on the Level 1 image. The selector box at Level 1 is 30 x 23 pixels, indicating a region 30 km x 23 km. The Level 2 image, pictured in the window-shot in Figure 2, is constructed from Landsat images and presented in pseudo-color, overlaid with graphics for county borders, roads, and feature names. The image is presented at 40-meter pixel resolution and size 768 x 576 pixels (or 30720 m x 23040 m) to fit well on a computer monitor. This particular image, corresponding to the position of the yellow selector box in Figure 1, is of western Hamilton County with the Platte River in the upper-left and the City of Aurora on the right. Level 2 also presents a yellow selector box, which the user moves over the field of interest and then clicks the mouse button to select.

At Level 3 of the Field Finder, the region indicated by the user on the Level 2 image is presented as a panchromatic digital ortho-photograph with 5 meter pixel resolution and size 768 x 576 pixels (or 3840 m x 2880 m). Figure 3 shows a region from western Hamilton County along Interstate 80. The images were created by down-sampling digital ortho-photographs from the Nebraska Department of Natural Resources

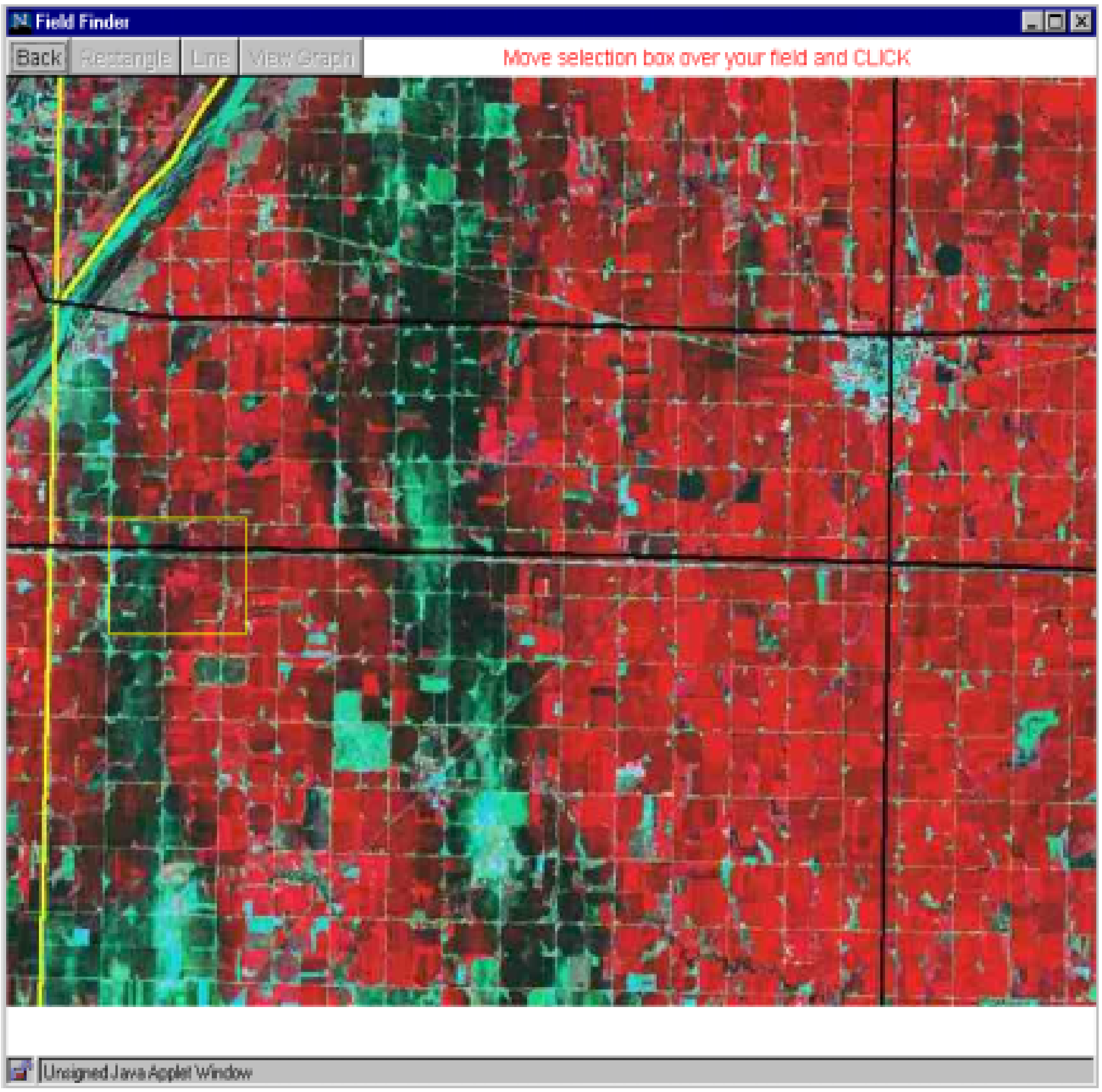

Figure 2. Field Finder Level 2 — pseudo-color Landsat image with feature overlays and yellow selector box, picturing western Hamilton County including Aurora and a small stretch of the Platte River (northwest corner).

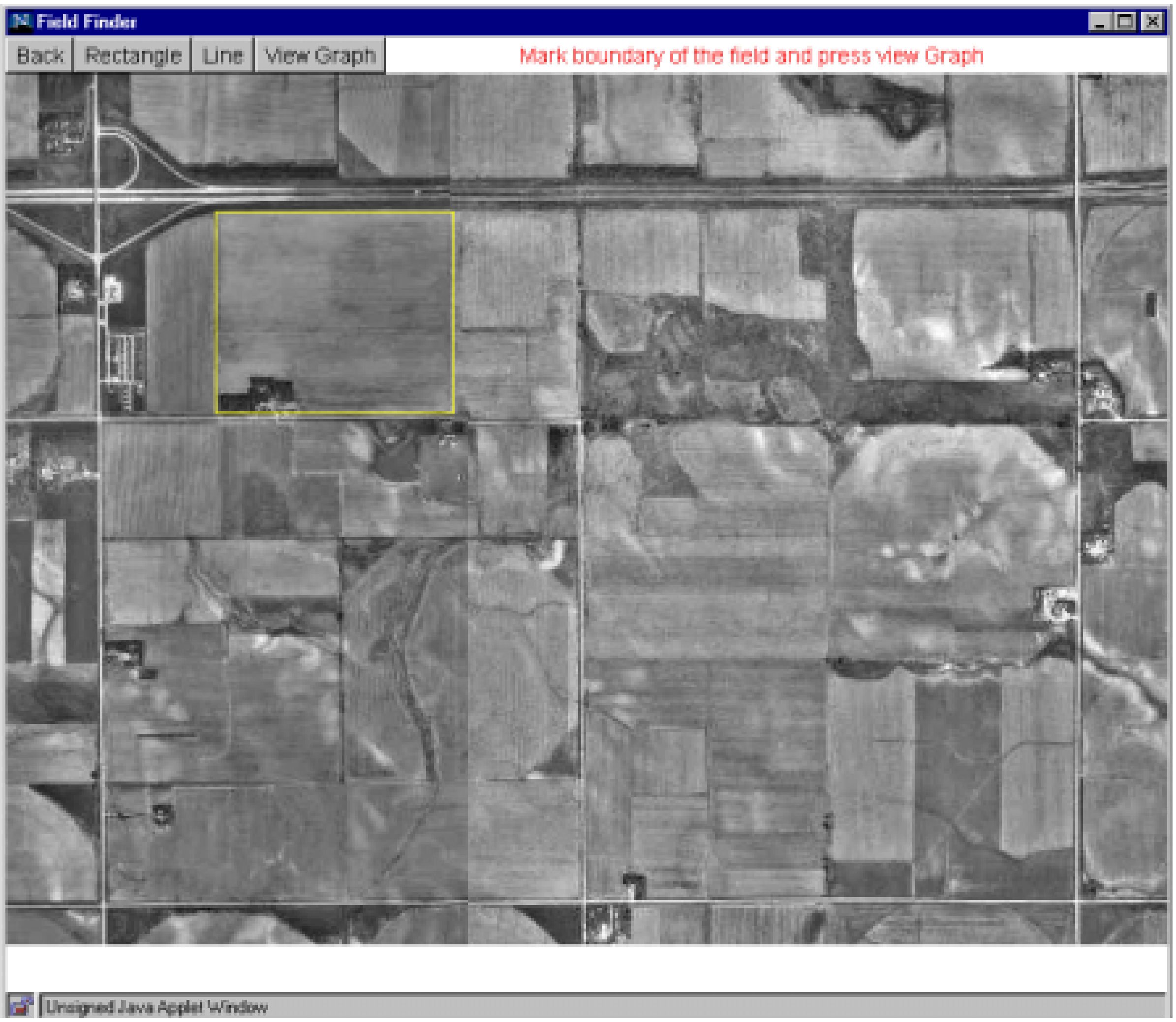

Figure 3. Field Finder Level 3 — panchromatic digital ortho-photograph along Interstate 80 in western Hamilton County, Nebraska, with rectangular field selection.

from 1 m to 5 m. At this size and resolution, the computer monitor contains a full section (1 mile square) both vertically and horizontally with room to spare. However, if the user focuses on the wrong area, the software allows backtracking from Level 3 to Level 2 and from Level 2 to Level 1. At Level 3, the user can outline the field with either a Rectangle or polygon Line drawing tool. The View Graph button indicates the user's final selection of a field as outlined and takes the program from the Field Finder tool to the Growing Season tool described in the next section.

GROWING SEASON

The Growing Season tool allows the user to set the planting date and the length of the growing season based on historical climate information, particularly heat units and risk of frost, and other considerations such as access to the field, short and long term weather forecasts, and risk tolerance. Neild (1983; 1986) and Nelson (1991) documented the relationship between heat unit measures, such as growing degree-days and relative maturity days, and the selection of corn hybrids for Nebraska. Typically, climatic parameters for selection of corn hybrids, such as frost-free period and accumulated heat units, are based on long-term averages by date (Andresen *et al.*, 1994). In the seed industry, the methods of calculating accumulated heat units and relative maturity days vary across companies and the definitions of early, medium, and late hybrids vary with geography and climatic settings (Andresen *et al.*, 1994). For example, some companies rate corn hybrid heat-unit requirements from date of planting and others use date of emergence (Stevens, 1985). A full-season hybrid matches the entire growing season available at a geographic location and will reach physiological maturity well before the first killing frost in the fall (Nelson, 1991; Roth, 1992; Andresen et al., 1992).

The Growing Season tool, illustrated in Figure 4, has four elements: a climograph with freeze risk and heat units, interactive sliders to set the planting date and maturity date, numeric values for growing season variables, and buttons to leave the Growing Season tool for the Hybrid Selector or Field Information Manager.

The Growing Season tool presents graphically and interactively historical climate information from the NOAA/NWS Cooperative Observer Network weather station nearest to the selected field. The climate information is drawn from the CLIMPROB dataset (Meyer, 1994; Meyer, 1996). Depending on the weather station, more than 100 years of data may be available. The data presented includes:

- Daily historical probability for the risk of freeze on or after a date in the spring and on or before a date in the fall.

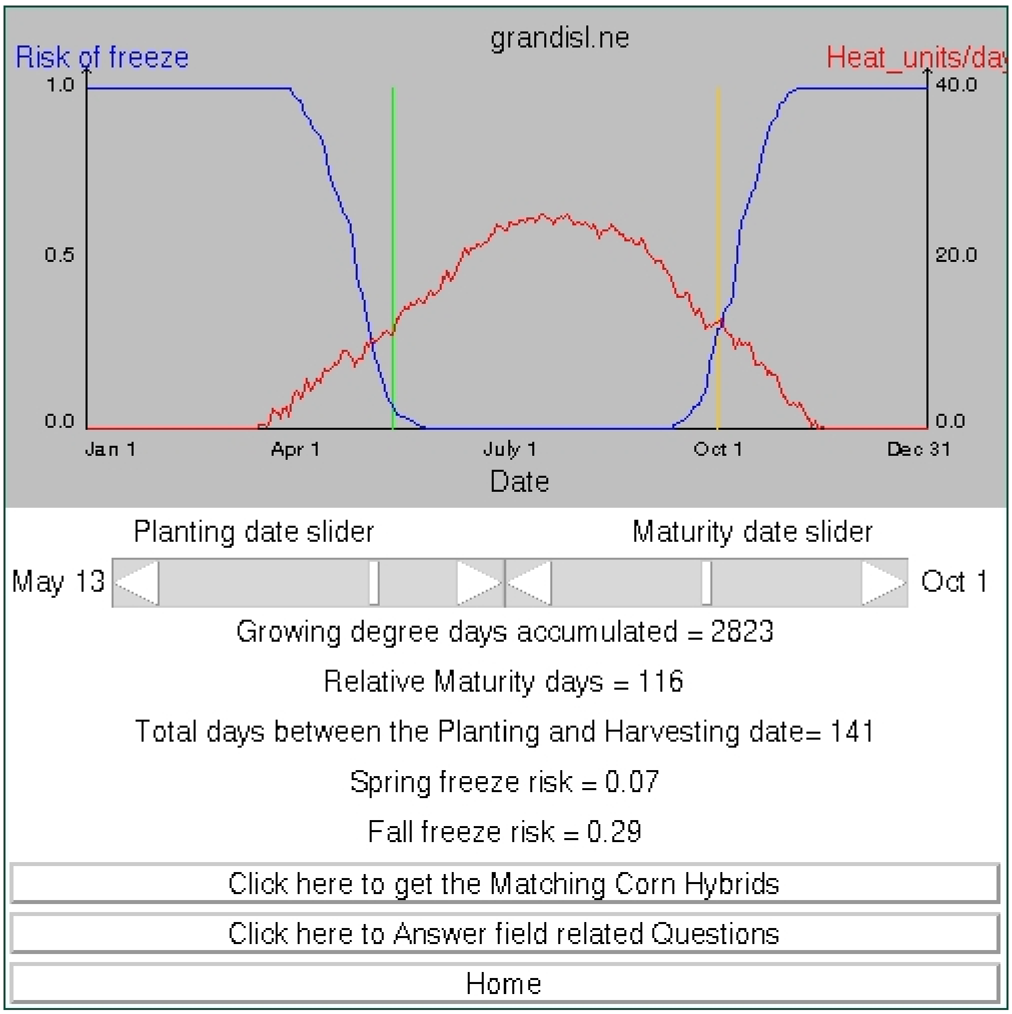

Figure 4. Growing Season tool with climograph, date sliders, numerical information, and navigation buttons.

- Daily historical averages for heat units. Heat units are computed from the daily historical average high temperature $A_{\max}$ and daily historical average low temperature $A_{\min}$ as:
$$\tfrac{1}{2}\left(T_{\max}+T_{\min}\right)-50 \text{ where } T_{\max}=\min[A_{\max},86] \text{ and } T_{\min}=\max[A_{\min},50].$$

This information is particularly valuable in Nebraska where the frost-free period ranges from 88 days in the northwest to 180 days in the southeast and the accumulated heat units range from less than 1900 in the west to about 4000 in the southeast (USDA/NRCS, 2001).

Two sliders control the planting date and the maturity date. As the sliders are moved, the dates are presented in text format next to the sliders and in graphical format with the green and gold vertical bars on the weather data graph. The user can slide the planting date later in the spring to reduce the risk of frost, but this also reduces the length of the growing season and the expected number of heat units during the growing season. Sliding the planting date earlier in the year increases the growing season length and the expected number of heat units during the growing season, but also increases the risk of spring freeze. Similar considerations exist for setting the maturity date in the fall. In setting the planting and maturity dates, the user also can consider such factors as access to the field and short and long term weather forecasts.

Expert knowledge is useful in balancing the freeze risk and accumulated heat units to account for crop ping practices (*e.g.*, plant populations), tillage management (*e.g.*, no-till versus conventional), and market strategies. For example:

- Corn for grain should reach maturity one to two weeks before the first killing frost.
- Longer season hybrids are used for silage production.
- In general, full season hybrids at any location will have the higher yields.
- Early plantings generally yield higher than later plantings.
- Earlier season hybrids may be more appropriate than "full season" hybrids in dryland production of western Nebraska despite a longer heat unit window because of available soil moisture.
- Soils under cooler, wetter conditions, north-facing aspects, and with high residue will slow germination and emergence.

As the sliders are moved to specify the start and end of the growing season, the program computes and presents numerically the growing season length (in days), the accumulated growing degree days (GDDs), the relative maturity days, and the risks of spring and fall freeze during the growing season. The GDDs are the accumulated heat units for all days between the planting and maturity dates designated by the user. Some seed companies, including The J.C. Robinson Seed Company (Golden Harvest brand) expresses the heat and growing season requirements as relative maturity days. The program computes this measure from GDDs using a regression equation derived for the suite of specific hybrids within this brand.

To view the hybrids appropriate to the selected growing season, the user clicks the button labeled "Matching Corn Hybrids". To record data about the field for archiving and later use in Plant Guide programs, the user clicks the button labeled "Answer Field-Related Questions".

HYBRID SELECTION

The Hybrid Selection tool, shown in Figure 5, presents a table of hybrids from the database that are appropriate for the growing season. Currently, this selection is based on Relative Maturity Days. The table contains vendor ratings for relative maturity days (±1 day window) and important secondary traits: drought stress, emergence, seeding vigor, and stay green. This part of the decision support tool will be changed on a year-to-year basis as new hybrids are introduced and others age out. Developing simple empirical relationships between the growing degree days and relative maturity is a key link in mapping where specific hybrids are adapted to the landscape.

Hybrids115

Matching Hybrids	days of Maturity	Drought Stress	Emergence	Seedling Vigor	Stay Green
H-9177Bt	113	7	7	7	8
H-9221Bt	113	8	6	7	9
H-9230Bt	113	7	7	7	8
H-2564	113	5	6	5	5
H-2573	113	9	7	6	7
EX99283RR	113	8	6	6	8
H-2581	114	8	5	6	8
H-9327IMI	114	8	6	4	8
H-9401Bt	115	5	6	6	8
H-9481Bt	115	7	6	5	9

Unsigned Java Applet Window

Figure 5. The Hybrid Selector with a table of hybrids appropriate for the relative maturity days of the selected growing season, including secondary characteristics.

Another button from the Growing Season tool allows users to answer and archive field-specific questions about the selected field. This information will be used in subsequent Plant Guide software to enhance automated decision support.

TECHNICAL DETAILS

The Planting Date Calculator makes use of several new information technologies. As in many industries, farmers and crop consultants are using of information technologies to increase productivity by better managing resources. Some of the barriers to the adoption of new technologies are the complexity of modern systems, the initial and continuing costs, and the rapid pace of change.

Delivery of applications over the Internet, as a service, without any required application-specific software or hardware, addresses some of the barriers to wider use of information technologies in small and medium sized businesses (Sun, 1999). The University of Nebraska – Lincoln (UNL) delivers the Planting Date Calculator in this way, acting as an application service provider (ASP). To use the program, the user needs only a compatible computer (e.g., operating Microsoft Windows™ OS or Unix™) with a color monitor (resolution of at least 1024x768 recommended), a recent version Web browser (e.g., Microsoft Internet Explorer™ or Netscape Navigator™), and Sun's Java™ virtual machine (Lindholm, 1999).

The user accesses the Planting Date Calculator through a Web browser, which communicates with the server computer at UNL using the Hypertext Transfer Protocol (HTTP) (Fielding *et al., 1999)* and lower-level Internet protocols. The user interface is delivered with an outer layer written in the Hypertext Markup Language (HTML) (Raggett *et al.*, 1999). The HTML documents include formatted text, graphics, and Java applets. The applets are programs written in the Java programming language and compiled into byte-codes that can be executed in the Java virtual machine (software that is able to execute Java applets). Like HTML, Java applets can present formatted text and graphics, but they can also perform computations, communicate actively with the server, and respond interactively to the user

The selector box in the Field Finder is an example of applet interactivity. The user interacts with the applet to drag the box around the image and select a region. Then, the application dynamically contacts the UNL server with the request for the image of the selected region. The Planting Date Calculator also includes programs that reside on the server to respond to the request.

The server programs are invoked using the Common Gateway Interface (CGI) protocol (Coar, 1999) for Web services. The Planting Date Calculator uses server-side programs written in open-source Perl; Research Systems Interactive Data Language™ (IDL) for image processing; and open-source PHP3. The image requested by the Field Finder applet depends on the region selected by the user. Therefore, the requested image must be computed when the request is made. The images of the entire state comprise a large data set, so the data is maintained on the server in relatively small files that are easily managed and accessed. Any requested image can be cut from the combined image formed from four of the small files (arranged 2 x 2). A server-side program written in IDL uses the request coordinates to retrieve the proper files and create the requested image. Images are compressed using the JPEG standard so that delivery is feasible even over an analog modem connection. The Hybrid Selector server-side programs are written in PHP3 and access a relational database maintained with the open-source MySQL database software.

CONCLUSIONS

Agriculture is large in the Nebraska economy with corn accounting for about $2B of annual production. With the Planting Date Calculator, the task of building systems to assist with the most important geospatial decisions in the State's economy has just begun. The project, funded by the Nebraska Research Initiative, has required a multi-disciplinary effort and new information technologies.

The principal application of the Planting Date Calculator is to assist farmers and crop consultants in selecting hybrids and scheduling planting. Relative maturity of corn hybrids is a primary characteristic to simultaneously manage freeze risk and yet seek higher yields by fully utilizing the available heat units. The Planting Date Guide matches the climatic parameters (frost-free period, growing degree-days, and relative maturity days) for a selected field with an appropriate suite of corn hybrids. The application is delivered as a service that does not require specialized hardware or software.

There are additional potential applications including crop insurance (*e.g.,* policies often include planting date windows) and drought mitigation (*e.g.,* early planting coupled with drought resistance and shorter-season hybrids can reduce water requirements and allow the crop to quickly develop an extensive root system that can reach deeper soil moisture). The program addresses several functions in a business model for seed companies:

1) assists sales and marketing with a confirmation tool that matches grower site characteristics with hybrid requirements,
2) provides technical agronomists a support tool for establishing strip trial locations and networks to help geo-reference fields and identify specific growing environments, and
3) identifies growing environments for targeting plant breeding and evaluate Genotype x Environment interactions (DeLacy et al., 1996).

Many improvements to the current software are planned or underway. Future goals include increased geographic coverage, additional geographic variables such as soil qualities, additional temporal considerations such as plant growth stages, additional crops such as soybeans, additional risk factors such as pests, field-scale variations for precision agriculture, cropping practices such as no-till cultivation, and economics (a priority, as suggested by the project advisory panel).

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