NEW AUTOMATED SYSTEM FOR INTEGRATED WEED MANAGEMENT IN SUGARCANE

By

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Abstract

A computer-based, automated system has been developed on a Windows environment and implemented in seven estates in Cuba, to assist integrated weed management in sugarcane. The knowledge base component of the system contains: extensive information on 32 weed species (including colour images of different stages), herbicides and herbicide treatments currently in use, expected levels of control for each weed species and crop-weed-environment conditions in which these treatments are recommended, productivity and costs of all chemical, mechanised and manual weed control operations and spray nozzle specifications. The expert decision-making system recommends best treatments, according to the number of reported weed species controlled, treatment costs and prevailing weed-crop-environment conditions, the amount of each product to be placed in the sprayer tank, the product mixing order by type of formulation and adds comments on sugarcane variety susceptibility. The system can also produce a detailed annual weed control plan for a farm, estate or sugar mill area. After entering relevant field information on prevailing weed species, crop cycles, expected yields, soil types and planting/harvest schedules and information on available herbicide spraying equipment, cultivation implements and manual labour; it enables a precise and quick selection of treatments and operations by fields or sets of uniform fields, compiles areas and inputs and offers reports on fortnightly and annual totals, by each type of weed management operation, as well as herbicide, spraying equipment, cultivation and labour inputs required and in deficit. It also supplies reports on individual field characteristics, including prevalent weeds, and field operation plans.

Introduction

Automated, decision-support, expert systems represent a new tool for integrated weed management programs to increase profitability while minimising environmental risk. Olesen et al. (1994) described an interdisciplinary project in Denmark, to develop a decision-making system for winter wheat, which comprises weed, pest and disease control, variety selection, planting density and timing, as well as nitrogen dosage and moment of application. Rydahl (1996) developed the decision-making system 'PC-Plant Protection' in Denmark for cereals, which, according to crop stage, expected yield and prevailing conditions, soil type, weed species and density, recommends best herbicide treatments and provides costs. Use of the system has resulted in a significant reduction in total herbicide inputs. Additionally, a decision-making system for conservation tillage systems in western Canada, which offers long-term management strategies to avoid adverse shifts in weed communities due to reduced tillage systems, has been developed (Derksen et al., 1996). It includes sections on weed identification and level of infestation, crop losses, long-term weed management and herbicide planning.

Pannell (2000), reported on the development of a decision support system for integrated weed management in rye in Australia, named RIM, which includes a wide range of treatment options besides herbicides. It simulates population dynamics, competition, costs, and profits for any specified weed management strategy specified by the user along a 20-year term.

The Bureau of Sugar Experiment Stations of Australia developed an Herbicide Expert System for Sugarcane (Coulston and Tilley, 1992). The system can be adjusted to the weed conditions of the three main cane-growing regions of Queensland. The Agronomy Department of Cuba's National Sugarcane Research Institute has been involved in weed management research and development for the last 35 years. During recent years, it has organised all training courses on weed management for personnel devoted to this field in sugarcane in all estates and farms throughout the country. In this regard, it undertook a project in 1995 to develop an automated expert system to assist growers and technical staff involved in weed management (Díaz et al., 1999). At present, PCMálezas is part of an integrated weed management assistance package implemented in several estates and offered to interested parties (local and foreign), including adjustment to local weed, herbicide, equipment, costs, husbandry conditions, and training of local staff.

Materials and methods

General features of the system

PCMálezas (version 1.2) is an executable program for Windows 32 bit operating systems. It requires an

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IBM or compatible PC, with a 486 or higher microprocessor, 8 MBytes RAM memory and 5 MBytes available space on the hard disk. Additionally, if the user wishes to access the images of the 32 weed species contained in its Knowledge Base, the system requires another 15 MBytes of hard disk space. For greater ease in the use of the system, a two key mouse, although not essential, is recommended.

PCMalezas has a friendly interface and through the main screen the user can interact with data in a clear and functional way. With the use of the menus and the tool bars, all options of the system can be accessed, while the status bar provides a brief description of the operation to be performed. PCMalezas was installed in 1999 in seven Agroindustrial Complexes (mill areas) of Cuba in the same number of provinces and in their respective Sugarcane Experiment Stations. To obtain satisfactory results with this system, data introduced must be complete, updated and reliable. The programming language used was Delphi 4.0 Client Server Suite and a relational data model was used to set up the system’s Knowledge Base. Copyright laws protect the system. A Help icon in the Tool Bar and a User’s Manual assist in understanding and operating the system.

Results and discussion

Although all modules of the system interact, PCMalezas can be divided into three main parts, according to their functions. They include the knowledge base, immediate (short term) herbicide treatment recommendation, and annual integrated (chemical, mechanized and manual) weed control planning.

Knowledge base

The knowledge base of the program provides screens to assist the decision-making process.

Available screens

The main weed species screen contains detailed individual descriptions of 32 different weed species commonly found in sugarcane fields. The information displayed includes: scientific names, common names (in Cuba and in many other countries), synonyms, descriptions, origins and distributions, means of propagation, hosts, uses and those considered as ‘problem weeds’. It also shows a colour image of the species, which can be easily enlarged, including in most cases, different stages: seedling, adult plant, flower, fruit and seeds.

The main herbicides screen contains a description of all herbicides currently used in sugarcane in Cuba. This option includes information on herbicide trade names, chemical names, available formulations, prices (in US$/kg or L), important physical and chemical properties, uses and sugarcane phytotoxicity.

The main herbicide treatments screen includes all herbicide treatments currently used in sugarcane in Cuba. This option offers the dosages of each component, type (moment) of treatment (preemergence or postemergence) and cost per ha in US$/ha. It also includes the conditions under which each treatment is recommended and its potential effect on the 32 weed species included in the knowledge base. These features can be viewed by pressing the ‘conditions of use’ and the ‘effect on weeds’ keys, respectively.

The main nozzles screen offers information on characteristics of the commonly used nozzles in sugarcane in Cuba. This option offers: type, code, colour, pressure and flow rate. It shows older trademarks and the newer ISO colours and codes, in order to avoid confusion.

The productivity of means screen offers information on the various options used in sugarcane in Cuba. This option offers a list of all chemical application, mechanical or animal driven cultivation and manual weeding methods available in Cuba with their respective productivity in area/day.

The operation costs screen offers information on the costs of the various weed control operations used in sugarcane in Cuba. The screen provided a list of all chemical, mechanized, animal driven and manual weeding operations and their costs in Cuban pesos and US$, as well as fuel consumption, per area.

PCMalezas can be updated annually or whenever necessary to account for changes in current herbicide costs and in registered and available herbicides; new weed control equipment, nozzles and research developments; and shifts in major weeds.

Immediate (short-term) herbicide treatment recommendations

Immediate or short-term herbicide treatment decision-making is an expert system that recommends treatments for any area, according to the number of weed species controlled among those reported as prevalent, treatment costs and prevailing weed-crop-environment conditions. Optionally, it lists the quantities of each product in a selected treatment to be placed in the sprayer tank and the treatment component mixing order. For some treatments, precautions regarding varietal susceptibility to the treatment are included. Required entries for this option include:

- sugarcane and weed growth stages;
- crop cycle, burned/green harvest and post harvest trash management;
- soil moisture;
- soil texture and organic matter;
- type of adjacent crops;
- up to four main weed species in the field, in descending order of prevalence;
- sprayer tank capacity (L) and final solution or spray volume (L/ha) if the ‘amounts of each product to be placed in the sprayer tank’ option is requested.

From these entries, the following outputs can be obtained:

- A list of all recommended herbicide treatments for the conditions specified, including estimates of weed control (‘controlled’, ‘suppressed’ or ‘not controlled’) and costs (in US$/ha). These are sorted firstly according to the number of reported weeds controlled (species number one
is imperative), and between treatments equal in this regard, by costs.

- Amounts of each product of a selected treatment to be placed in the sprayer tank.
- Mixing order of treatment components, according to type of formulation.

**Annual integrated weed control plan**

PCMalezas is a system aimed for use by sugar-cane estates, mill areas or sections of the former (farms). After installing and for the first time running the system a process of personalisation, in which the property’s data (name, code and province/state) and year of planning are defined.

**Data import**

PCMalezas imports automatically field data based on a farm code, block (set of fields) and field numbers, estimated cane yield at June 30, natural drainage and present crop cycle from the agricultural data base. It requires information to be completed on the field’s forthcoming crop cycle (including burn/green harvest and trash management in ratoons) as in previous sections of the system, and harvest (in ratoon) or planting (in plant cane) fortnight schedule, in a numerical sequence, linked automatically to a I or II fortnight/month variable. For foreign users, the system can be modified to enter this information manually.

**Use of bars and calendar**

The status bar, the tool bar and the calendar are parts of PCMalezas developed to aid users:

- By means of the status bar the user receives a brief description of the system’s options by placing the mouse’s pointer over the desired option;
- The tool bar offers quicker access to the most commonly used options by an icon visible in the main screen;
- The calendar is useful for planning calculations and can be kept visible as long as desired.

**Data organisation**

In order to carry out the planning of a given farm (section of an estate or mill area) or of a block (set of uniform fields), it is useful to identify the production unit. When the screen, ‘fields included in the weed control campaign’ is selected, all field data can be kept in the background for consultation when other steps of planning are being carried out. With this screen, corrections or additions to field data can be made. Additionally, by clicking an icon, selected fields can be sorted by their farm, block or field number, in order to facilitate all steps: completion of field data, introduction of the weed species survey and the weed control means survey and the actual field planning. Furthermore, by a right click with the mouse on a given field in this screen, options of viewing the weed species survey, the weed control means survey or the actual plan for that field, is offered.

**Weed species survey**

A weed species survey must be implemented and introduced in the system as a means of deciding on possible weed control options for field planning. This survey can be entered either by independent or sets of uniform fields. Up to four prevalent species among the 32 included in the knowledge base can be reported for any field or set of uniform fields. In case of species considered as ‘problem weeds’, the percentage infested area of the field or set of fields is also required. Arrows that allow the user to access weed names, field numbers and percentage numerals facilitate this process. Furthermore, an icon adjacent to each weed slot enables the user to see the selected weed’s image, in case of doubt.

**Weed control means survey**

The weed control treatments survey is an electronic inventory of existing and reliable means for herbicide application, mechanised or animal driven field cultivation and manual weeding in each farm, section of estate or mill area (previously selected). In case of aerial application, the system requires only the possibility of use in that given area.

**Planning**

After completing the various steps selecting a given farm, section of estate or mill area or a block of fields, the system allows the user to carry out the actual planning of all weed control operations. The system automatically sorts all fields in the selected area according to crop cycle and planting/harvest schedule (fortnight/month).

If the ‘multiple field planning’ option is chosen, the user must select, in an additional screen, sets of fields with similar quantities and types of weed species. Also fields with poor drainage or with forecasted yields below certain minimum thresholds cannot be coupled to others that are not influenced by these factors, because the system restrains herbicide use in the former and adds certain preemergence treatments in ratoons in the latter. Certain notations facilitate this. If a set of fields is not uniform, the system will reject it and specify the cause.

After selecting the field or set of uniform fields, the system offers options of weed control operations in different stages of crop growth, beginning with a pre-planting herbicide cleanup and ending with a pre-canopy closure herbicide application or, in case of creeping vines, an aerial application of a post-canopy herbicide. The system takes into account crop cycle, period of the year and trash management (in ratoons) to design the number, type of possible operations and their frequency. It also takes into account prevailing weed species; soil types and available equipment, implements and labour in order to select the best herbicide treatments and weed control methods. The user is required to select among possible options in each stage of the crop, as well as the type of application equipment (knapsack, tractor-mounted or aerial), type of implements and/or manual labour. In the case of herbicide treatments, these are sorted according to costs. Whenever possible the system
offers combinations of mechanised (or animal driven) cultivation of interrows with band application of herbicide or manual weeding on the line of sugarcane.

As the user defines operations, these turn blue in the general plan chart and, when all operations are planned, a 'plan' key is developed which allows the entering of all selected options. Afterwards the selected fields plan, with all selected options, can be edited in an 'edit screen'. The weed species and the weed control means surveys can be viewed, but not modified through an icon from this section.

The system, in order to estimate and compile herbicide inputs required, also takes into account (through correction factors) forecasted cane yield, crop cycle, and green or burnt harvest and trash management. In cases of spot application against 'problem weeds' and band (row) applications, it calculates and compiles herbicide requirements for net areas.

Farm staff unfamiliar with computer operation can use a set of optional, coded forms to assist them in determining prevalent weed species and filling in numbers of available sprayers, implements and labour and in selecting among possible herbicide treatments, types of sprayers, implements and manual labour for various crop-weed-soil situations. The coded information from these forms can be entered in the system by an estate's weed management technician or PC operator.

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Reports
Once annual planning has concluded, it is possible to obtain through the screen or printer various reports. These include the following:

- Field cultivation areas fortnight and annual plan.
- Herbicide application areas fortnight and annual plan.
- Manual weeding areas fortnight and annual plan.
- Partition of the weed control area plan by weed control means.
- Herbicide product fortnight and annual requirement plan.
- Weed control means (sprayers, implements and manual labour) fortnight and annual requirements and deficits.
- Plan of operations to be carried out in each field.
- List of field characteristics, including prevalent weeds.

Future improvements
In 2001, the system will include facilities to link to an available and simple geographic module to produce various report maps and will extend its integrated weed management scope to include other cultural practices, as reported by Diaz and Labrada (1994, 1996).

REFERENCES

UN NOUVEAU SYSTEME INFORMATISE POUR LA GESTION INTEGREE DES ADVENTICES DANS LA CANNE A SUCRE

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Résumé
Un nouveau système informatisé a été développé sous le système d’exploitation Windows et mis en application sur plusieurs sucreries, pour la gestion intégrée des adventices dans la canne à sucre. Il comprend les trois parties suivantes: Une base de données incluant des informations détaillées sur 32 principales espèces d’adventices dans les champs de canne à Cuba (avec des photos en couleurs à
NUEVO SISTEMA AUTOMATIZADO PARA EL MANEJO INTEGRAL DE MALEZAS EN CANA DE AZÚCAR

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Resumen
Se ha desarrollado sobre ambiente Windows e implementado en siete ingenios de Cuba el sistema automatizado PCMalezas para contribuir al control integral de malezas en caña de azúcar. Una base de conocimientos incluye una extensa información sobre 32 principales especies de malezas (incluyendo imágenes a color de diferentes estadios), los herbicidas y tratamientos de estos actualmente en uso, sus efectos en cada una de las anteriores especies y las condiciones de uso del cultivo, malezas y ambiente en que se recomiendan, información sobre costos y productividad de todas las labores de control químicas, mecanizadas, por tracción animal y manuales y especificaciones sobre boquillas. El sistema experto para la toma de decisiones recomienda los mejores tratamientos de herbicidas, de acuerdo al número de especies reportadas que controlan, sus costos y las condiciones prevalecientes de cultivo, malezas y ambiente; las cantidades de cada producto a echar en el tanque de la aspersora, el orden de mezclado y agrega comentarios sobre susceptibilidad varietal. También ofrece un detallado plan anual de control integral (herbicidas, cultivo de desyerbe y escarda manual) para cada finca y todo el ingenio Para ello, después de introducir información por campos o grupos de campos uniformes sobre malezas predominantes, ciclos y tipo de cosecha, tipos de suelos, rendimientos estimados, programación de siembra o cosecha, así como de la disponibilidad de medios de aplicación, implementos de cultivo y fuerza de trabajo para la limpieza manual por finca, permite una rápida y precisa selección de tratamientos y medios por campos o grupos de campos uniformes, compila las áreas, medios, insumos y fuerzas necesarias y al final presenta reportes anuales y por quincenas de áreas por cada tipo de labor de control, así como de las presentas de herbicidas, medios de aplicación, implementos de cultivo y fuerza de trabajo necesarios y en déficit. También brinda reportes por campos de sus características, incluyendo malezas predominantes, y su plan de labores.